Article

Systems Dynamics and the Analytical Network Process as A methodology for the Evaluation and Prioritization of Green Projects: A New Proposal that Involves Participative Integration

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Abstract: Citizen participation has always been of vital importance in decision-making processes and, likewise, joint work in the formulation and execution of projects that respond to territorial needs. This in order to ensure the best impact of public or private investment, optimizing the result and community articulation. For this reason, this investigation proposes a methodology of evaluation and prioritization of projects based on an approach integrated between the modelling in dynamics systems (SDM) and the Analytical process network (ANP), in which the citizen factors are used as qualitative and quantitative variables inside the posed balance sheet model. This is how the model developed by the Stella Architect software, it offers to the decision makers approximate information about the reality of the community, especially those who were affected by the Colombian conflict and where the expectations of a comprehensive repair could disrupt the socioeconomic system and reveal more pressing interests than those of the central government. The methodology is described by the information gotten through the participatory workshops done in the California county that belongs to the Magdalena region, this is a very affected region by the conflict in Colombia. The investigation results confirm the useful of, first of all, the use of the modelling as an information-generating tool by allowing the simulation of relevant variables in the evaluation and prioritization of projects at different moments of time and, in second place, use the knowledge of the experts that expose the ANP method for establishing the importance of each variable compared with other variables and, likewise of each project compared to the rest of the alternatives in each of the different instants of time in which the evaluation is carried out, given that the results could change in any time, the official ranking is showed after an optimization process with partial results.

Keywords: community participation; Systems Dynamics Model; sustainable development; multi-criteria decision-making (MCDM); analytic network process (ANP)

1. Introduction

The final document for the end of the Colombian conflict [1] is composed by various agreements focused to contribute to the implementation of the constitutional rights of the Colombian people so it is very important the citizen participation in the construction of the peace, likewise, in the planning, realization and the monitoring of plans, programs and works in the territories, that guarantees the socio-environmental sustainability, infrastructure development, effective use of rural land and land use planning [2].

When we talk about socio-environmental sustainability, the importance of protecting areas of environmental interest is highlighted and at the same time efforts are coordinated to improve the offer of employment, economic and welfare opportunities for men and women that belong to these communities under the principles of participation and aimed at sustainable development [3].

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The implementation of the agreement seeks, among other things, the construction of development and well-being in the territories and the reduction of the gap between urban and rural areas through a review and analysis of the conditions, needs and characteristics of economic, cultural, and social nature that makes each territory and community a unique scenery in which the citizen participation allows decision-making to be carried out in a comprehensive, coordinated and adapted manner to each case [4].

The citizen participation coordinated with the intervention of the territorial and civil authorities in charge of the conservation of freedom and the rights of the victims of the conflict, this contributes to recovering the social fabric, through the recognition of the victims, the construction of historical memory and the purpose of non-repetition, encouraging a tolerance culture, respect, and confidence; they were lost due to the conflict [5].

So the evaluation and prioritization of the projects, in the times of the post-conflict in Colombia, is showed as a dilemma of where is the best place to take the best decisions of investments by not only the local governments, also the central government, with the main goal of an effective repair of the damages caused to the community, so that allows overcoming many decades of conflict without the attention of the government [6].

However, in many times current rural and urban agendas respond more to political and/or economic commitments and obligations, so they never attend the problematics, needs and expectations of the community [7]. When the previous issues like the participations and the citizen factor, the natural resources, sustainability, projects, and government incentives take more importance in a systems dynamical model, it is possible to generate strategic information to evaluate and prioritize development alternatives for the communities in the conflict. And, at the same time, bias in decision making is minimized, setting aside the political and/or economic component, through a multi-criteria evaluation such as the method proposed in the Network Analytical Process (ANP) [8], it will be possible to better address the problems and needs of the community affected by the conflict.

In this way, the proposed socio-economic and environmental system allows interpret and integrate citizen factors within a model in System Dynamics which absorbs, adapts and answers that factors determined specifically for the community, through participatory workshops that were created by the Participatory Rural Diagnosis methodology [9], [10]. So far there are few applications where the modelling methodologies in system dynamics are integrated with the multicriteria evaluation ANP [11], and it has not yet been possible to find any related to the evaluation and prioritization of projects.

In this work it is illustrated an integrated assessment approach based on Network Analytical Processes (ANP) [12]–[15] and System Dynamics Model (SDM) [16]–[19], according to its methodological background and operational characteristics. The main objective of this article is to expose this methodology in order to facilitate decision-making in the evaluation and prioritization of green projects. The foregoing using the supply and demand of natural resources of water and land as main variables within a balance model. Likewise, citizen factors (found through community participation) are used, and its influence in the rest of the modelling. Through this approach, experts can target planned investments and incentives from different scenarios and at different times to arrive at an optimized selection.

The document is structured as follows: section 2 illustrates the model in System Dynamics; in section 3 presents the validation of the model through the sensitivity analysis; then in section 4 the elaboration of the structure of the ANP network is exposed from the identification of the clusters and nodes in the model in Systems Dynamics; section 5 exposes the application of the evaluation and prioritization methodology to an specific case of study; section 6 presents the results; then, section 7 exposes the discussion, at the end, the section 8 shows the conclusions and comments with prospects for future research.

2. System Dynamic Model

The proposed methodology has been carried out through a two-stage structure. The figure one shows the general approach for its application and adaptation to the specific case study. The first stage consists of the elaboration of the model in System Dynamics through different steps.

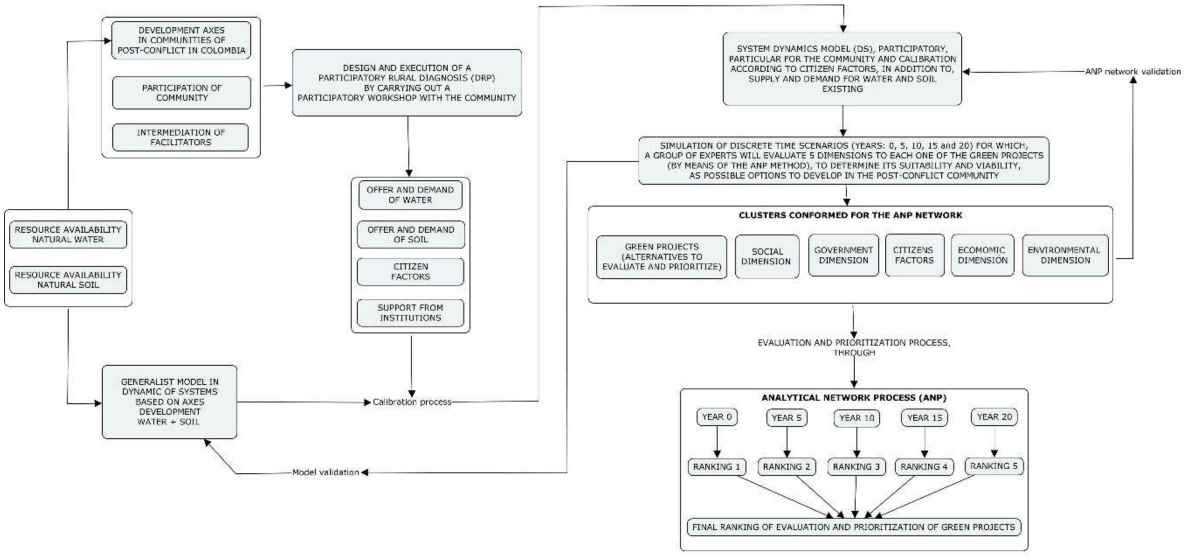

Figure 1. Methodological development.
Source: authors' own creation

The first step in the creation of the modelling is the problem identification. In our case, the problem lies in how to improve the ability to evaluate and prioritize green projects, knowing previously that the main problems and the delay development of the communities that belong to the post-conflict period in Colombia [6], [20], are related with the availability and the use of the natural resources like the water and the land [1], [5], [21], [22]. That evaluation and prioritization capacity is understood as the selection of the most appropriate projects that can respond to the problems, needs and expectations of the community [19], [23]–[26].

The second step was the hypothesis planning, through which it is exposed that it is possible to anticipate where and at what moment of time to direct investments in green projects; keeping in mind, first of all, the availability and the use of the natural resource of the water and land (supply and demand relationship), and in second place, citizen factors determined directly with the community through participation workshops.

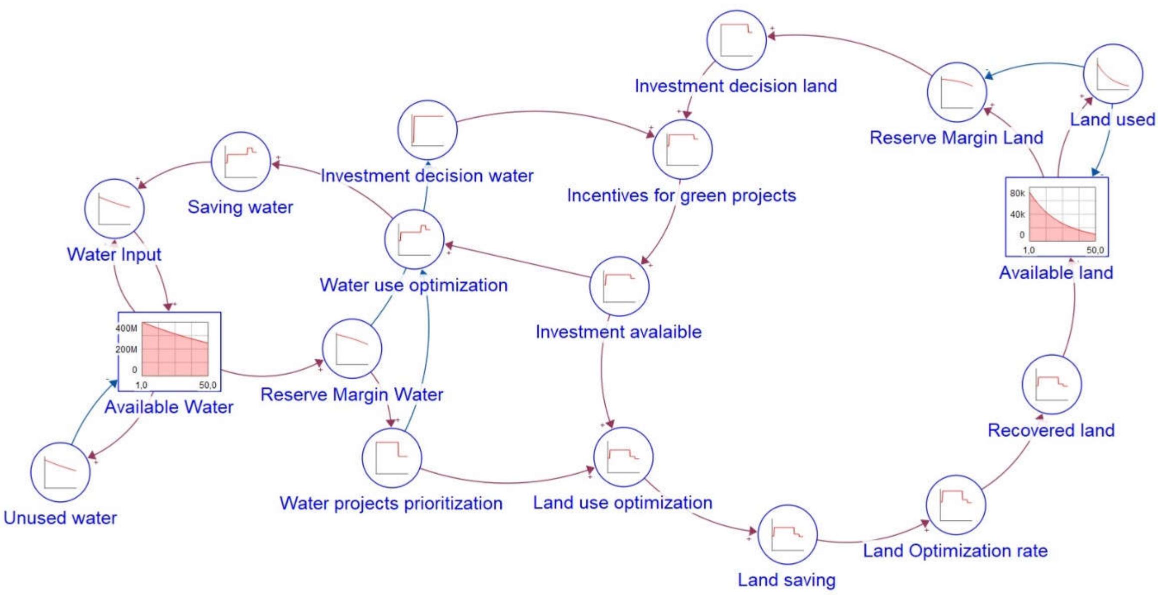

Figure 2. Casual loop diagram.

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In the third step for the creation of the modelling, we made the casual loop diagram or CLD (figure 2) [27]–[31], in which we identify the relationships between state variables set (supply and demand for water; supply and demand for land; and, of course, population), likewise the different parameters, among them the citizen factors. The fourth step was the creation of the stock and flow diagram or SFD (Stock and Flow Diagram, Figure 3) [29]–[32], in which the casual loop diagram is complemented by secondary variables and parameters in order to simulate the behavior of the system over time.

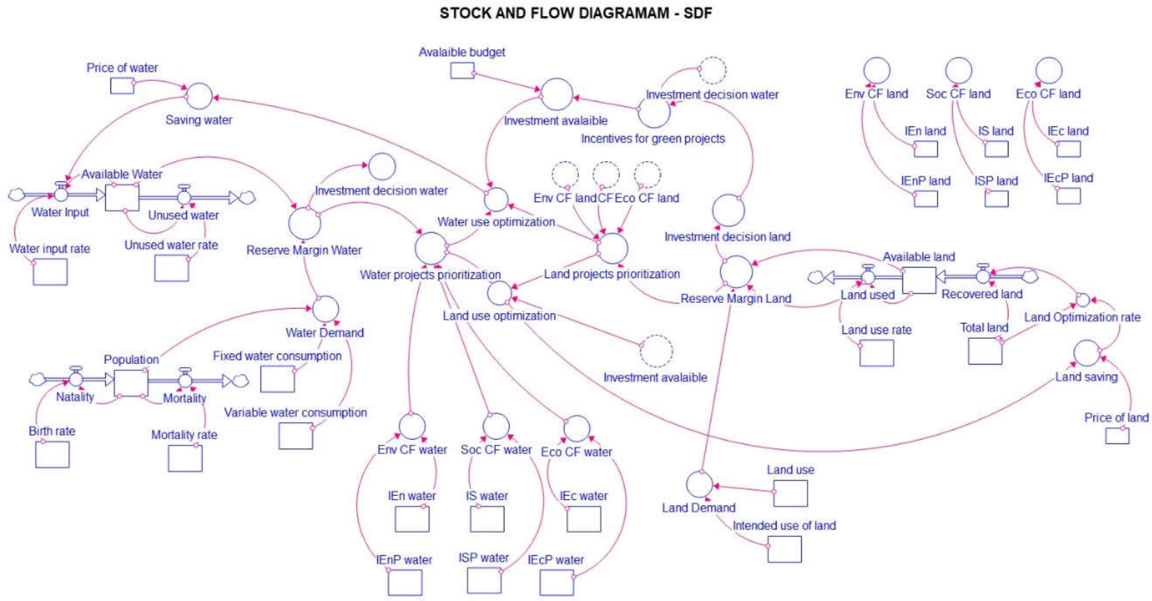

Figure 3 Stock and Flow Diagram-SFD
Source: authors' own creation

3. Validation of model in System Dynamics

There are 3 cases of sensibility analysis for the models based in system dynamics numerical sensitivity, Mode of behavior Sensitivity, and policy implementation sensitivity. After having defined the model that will be applied to generate scenarios in the evaluation and prioritization of green projects, it is very interesting to explore the numerical sensitivity, because with this one, it is possible to show the adjustments that are required to be carried out in order to validate the hypotheses initially raised.

The numerical sensibility occurs when changes in the assumptions alter the numerical results. For example, If the water input rate in the model is changed, it will be observed how the output is altered in the Available Water level variable. All the models show numerical sensibility [29], and it is possible to observe how a reduced set of scalar factors can characterize the multidimensional uncertainty in a summarized, but exhaustive way [33], [34]. The proposed model for this thesis, shows two parameters that are of interest and that are directly related to the level variables, the water input rate, in the Available Water level variable and the land use rate, in the Available Land level variable. To carry out the numerical sensitivity analysis, a window was taken for the water inlet rate between 0,0 and 0,45 and a window for land use rate between 0 and 0,20 and the Montecarlo method that is included in the simulation package was used Vensim Pro, the figures 4 and 9 show the results. Due to solutions map is very big, the Vensim Pro software was configured to make at least 2000 executions of the algorithm so that the results were consistent and likewise, cover all possible numerical solutions for those ranges of the parameters. It is important to mention that, for the sensitivity analysis, the uniform random distribution was used by means of which a fixed variation of the parameters is guaranteed.

In figures 4 and 5, the sensitivity analysis of the variables Available Water and Available Land, manages to establish a range, in which the dynamics of the system evolves and makes feasible the projects that can be developed according to the assumed parameters and those that were obtained with the help of the community in the participatory workshops carried out. In this way, the model provides to the experts a first selection criterion and becomes a filter that can be exploited by decision makers during the development of the peer evaluations proposed in the Analytical Network Process (ANP) and that will be seen in the next chapter. Once the projects are framed within this range, analysis efforts can be concentrated on the other variables of the system that account for other important factors within the complete evaluation and prioritization process.

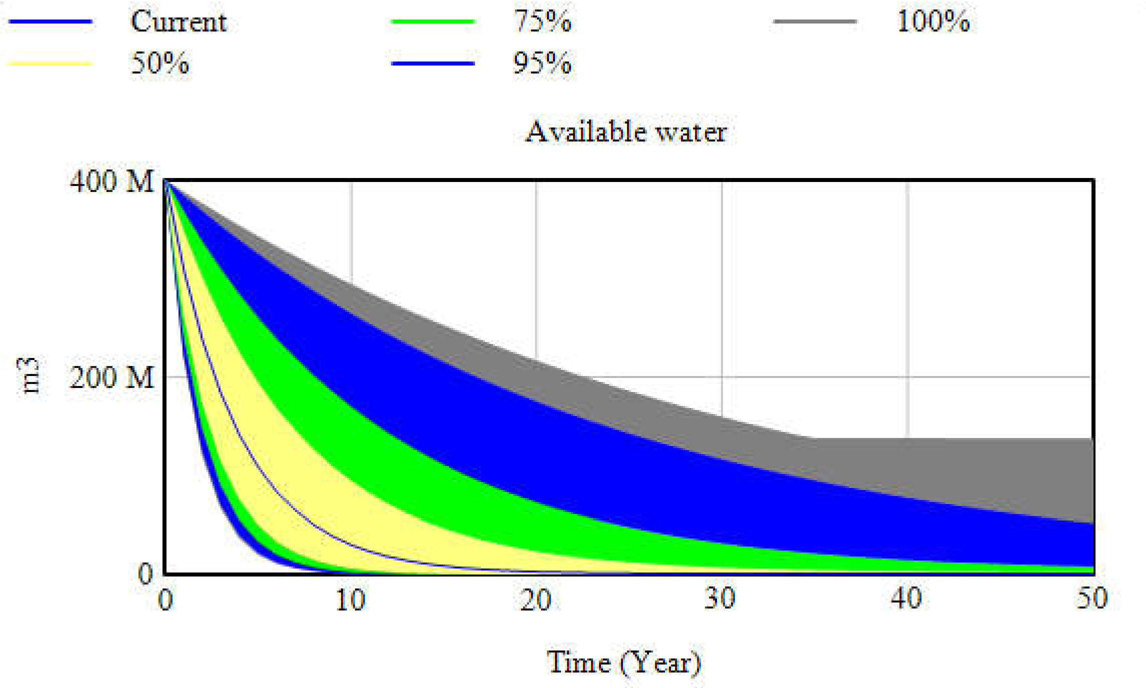

Figure 4. Sensitivity analysis of the Available Water level variable.

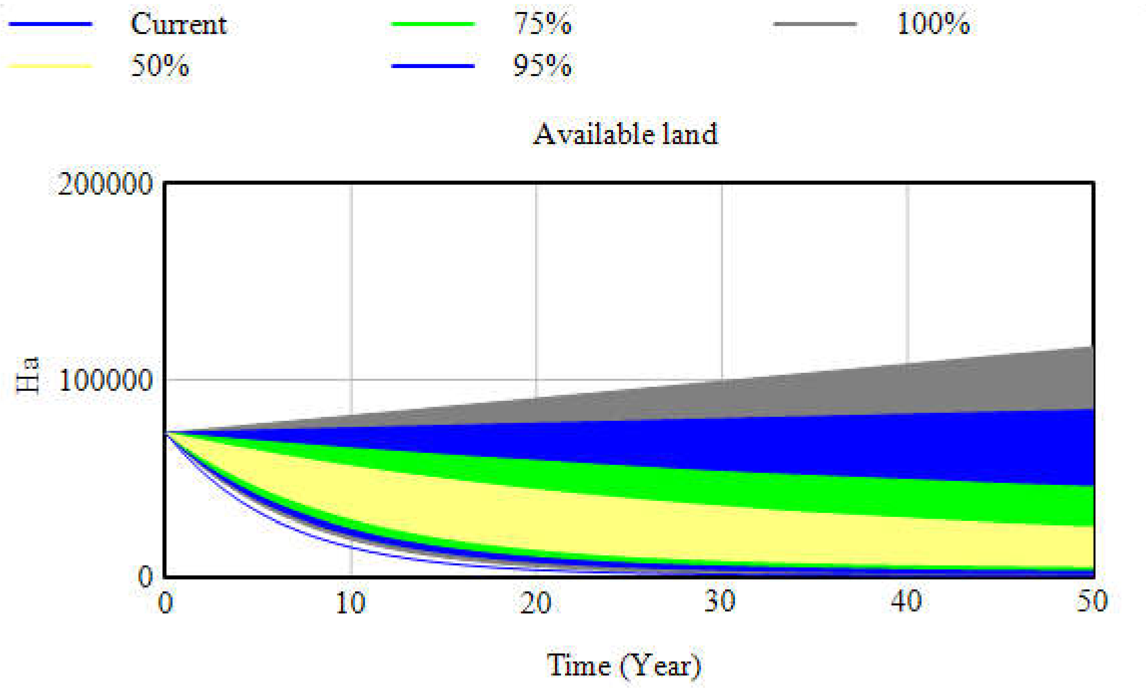

Figure 5. Sensitivity analysis in the level variable Land Available.

Now, in Figures 6 and 7, the sensitivity analysis focuses on the variables called reserve margins, both water and soil. This time, the sensitivity shown by these variables accounts for the narrow margin that exists between the use and abuse of natural resources of water and land, which in turn, can mean their abundance or scarcity. Therefore, this analysis could also guide investment decision-making regarding one or another project, depending on the community and depending on the availability of resources in the area.

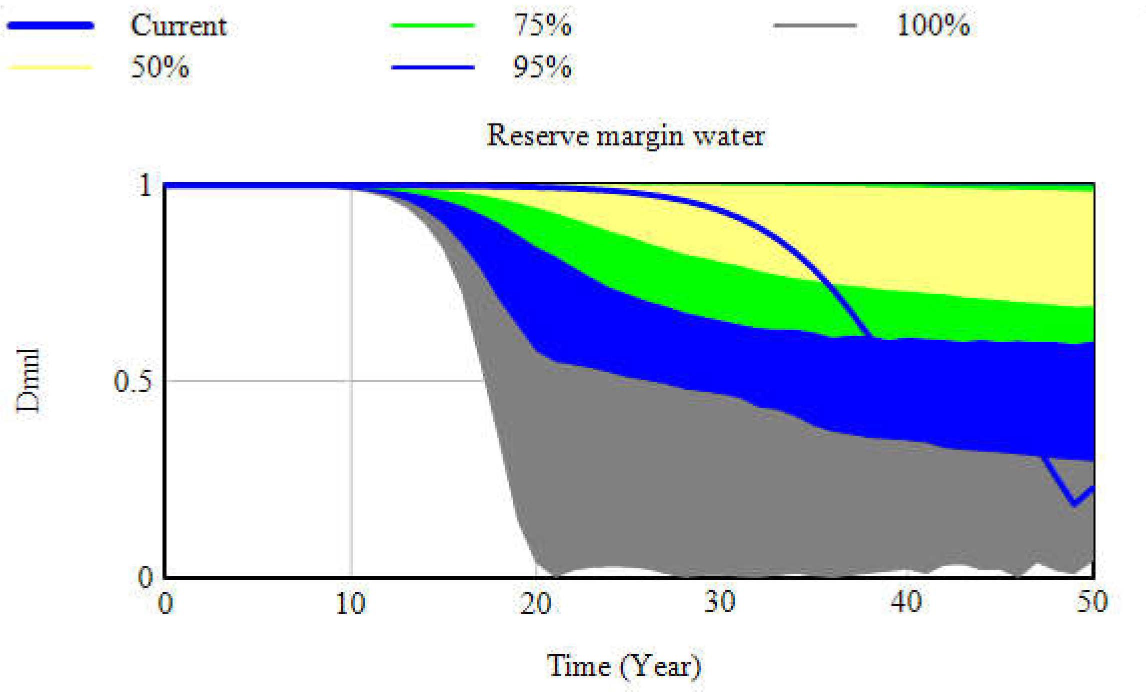

Figure 6. Sensitivity analysis in the Reserve Margin variable (water).

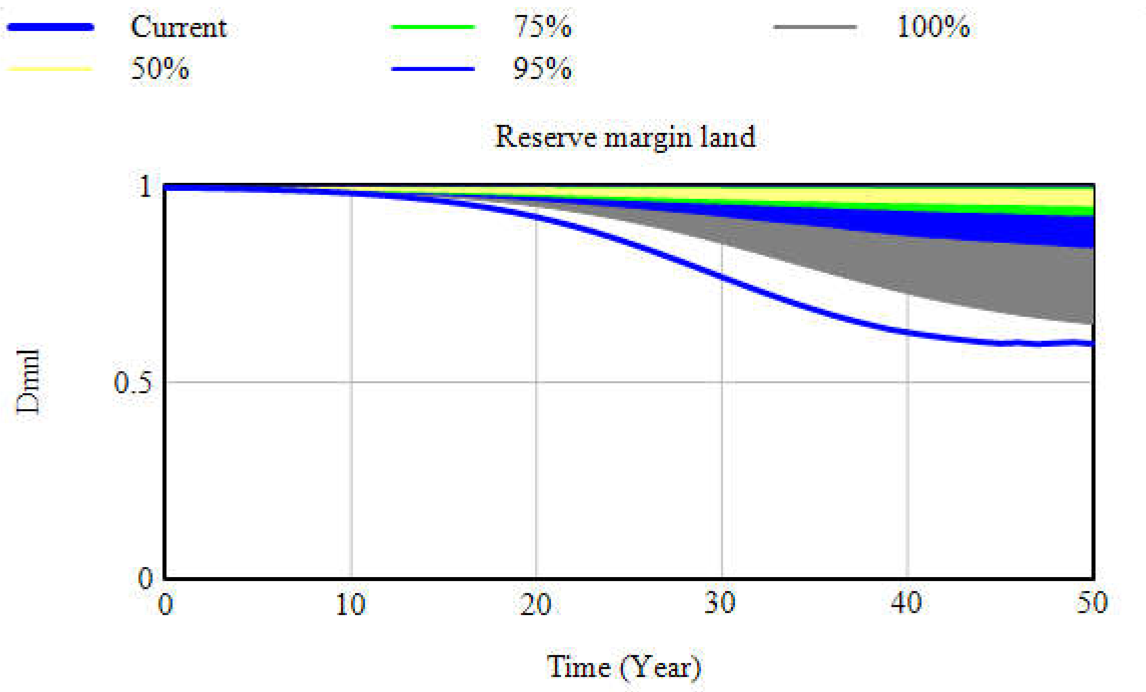

Figure 7. Sensitivity analysis in the Reserve Margin variable (land).

On the other hand, when the project prioritization variables are analyzed, Figures 8 and 9, a lower degree of sensitivity is evidenced, that is, more monotonous behaviors in the system, due to the fact that such variables are directly influenced by the factors

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citizens. However, everything will depend, again, on the availability of natural resources in the area at the time of evaluating and prioritizing the projects, and the problems and needs of the community that can be quantified in the citizen factors, with which calibrate the model.

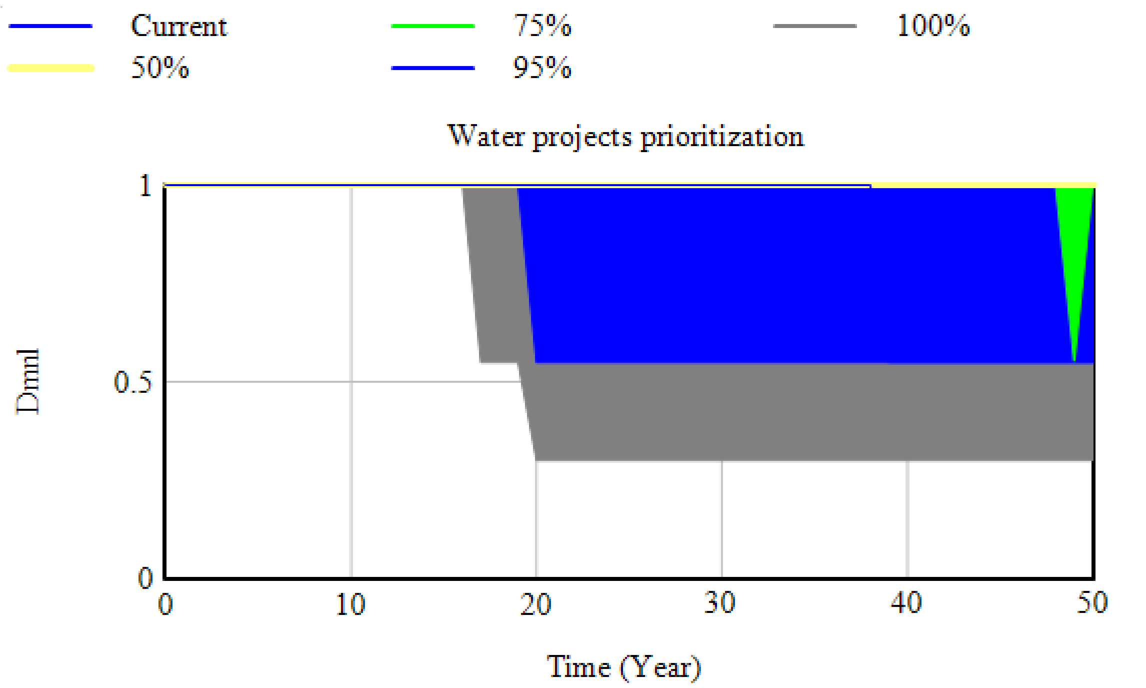

Figure 8. Sensitivity analysis in the project prioritization variable (water).

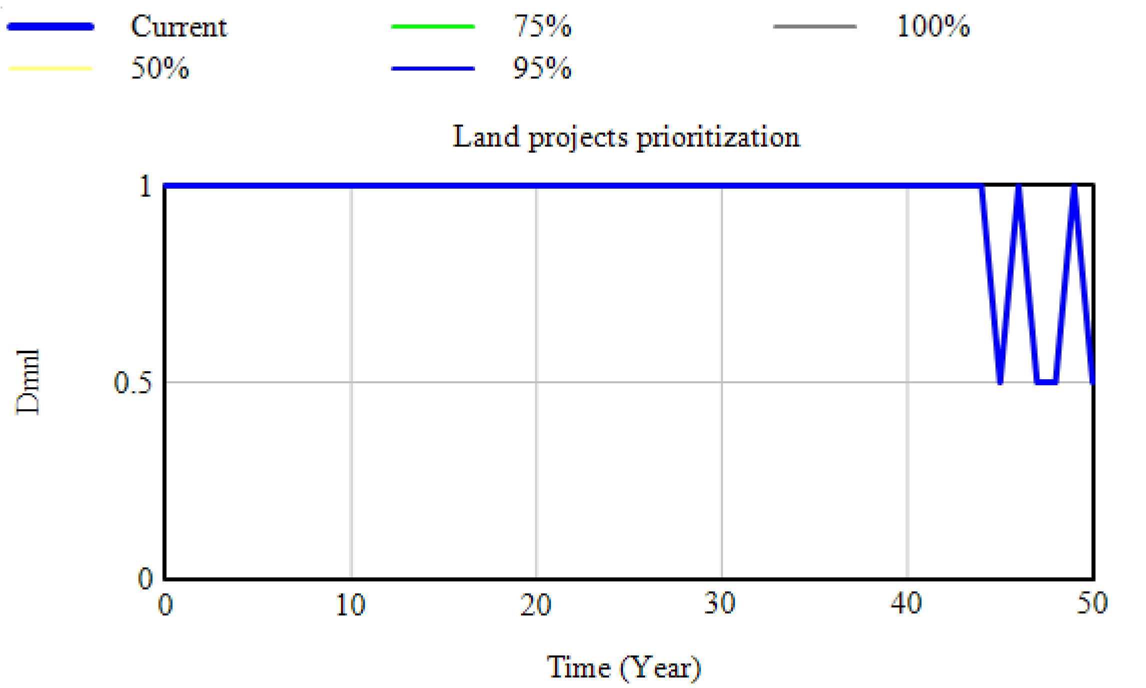

Figure 9. Sensitivity analysis in the project prioritization variable (land).

3.1. Exploitation of the model

Validation techniques tend to identify if the model that is available is faithfully coupled to the real system or phenomenon that is being analyzed. However, when behavior patterns change as model assumptions change, we talk about sensitivity in the way of

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behavior [35]. These changes in assumptions can occur during the model optimization process, when it is necessary to modify a pattern that has been diagnosed as inconvenient or negative. Faced with the new alternatives, the model could go from an oscillatory behavior to a monotonic behavior. in this point, it is then also possible to use the tools that come with software like Vensim Pro, Stella Architect or any other type of software based on System Dynamics, in order to obtain a more rigorous analysis of the system.

In short, it is possible to use these tools in models that can be represented by systems of ordinary differential equations and that additionally present no smoothness or jumps in their functional expressions. The given tools by Vensim Pro and Stella Architect allow to show some phenomena associated with the use of stepped functions and thus evaluate alternatives and additional information in order to exploit the model in a better way.

For the model shown in the figure 3, the auxiliary variables Optimization of Water Projects and Optimization of Land Projects are step functions, which in turn depends on the Reserve Margins (Water and land, respectively) which are equally non-smooth. Hence, it is of great interest to evaluate what happens with investment decisions and the optimization of water and land use, when citizen factors are altered. In the figure 10 we can see for each value of each one of the citizen factors in the interval between 0 and 1, the output in the variables Prioritization of Water projects and Prioritization of land projects shows a variation of less than 50% during the first 30 years, but varies substantially during the last 20 which is the time in which it is most affected by the alteration of the variables related to the reserve margins (MRA and MRS) which are very important at the time of evaluating and prioritize possible projects to be carried out. In this case, projections are made on these auxiliary variables, to understand how they are affected by specific values in the parameters of citizen factors. The greater variation at the end of time implies changes in investment decisions, which would lead decision makers to move towards other types of investments, such as social or environmental, that respond to the conditions of the moment. With this tool given by Vensim Pro sensitivity to ways of behavior is examined, that is, for values around 0 the dynamics system is monotonous, meanwhile for values above 0,5 oscillations occur. It is worth mentioning that these behaviors are within the possible intervals that a rural community would face in a post-conflict period, which is characterized by a monotonous and slow behavior associated with the speed of development, so for decision makers in the evaluation and prioritization of green projects, it is very important to know what happens before a change in the parameters in the medium and long term and not as is normally done when studying dynamic systems in their stationary state.

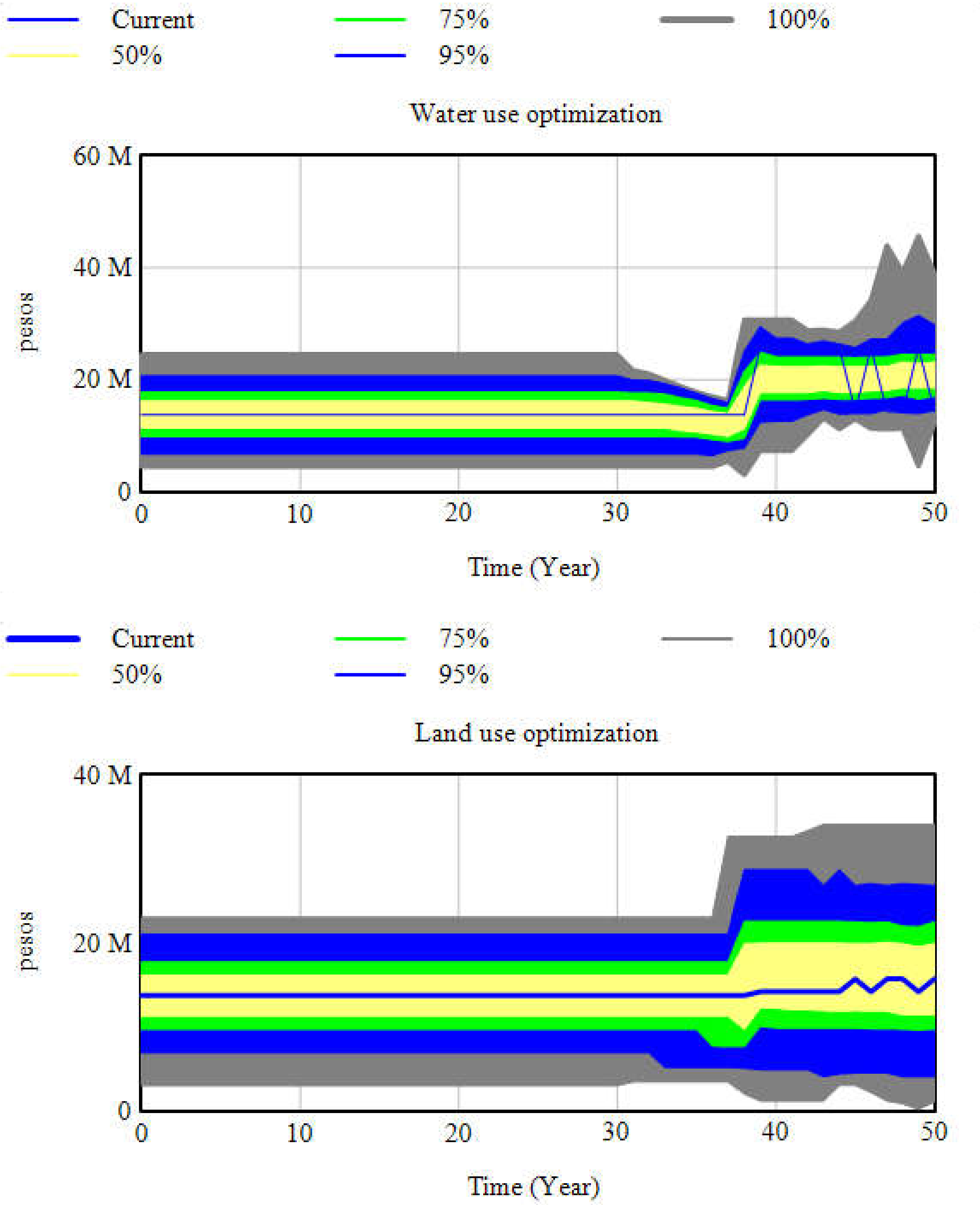

Figure 10. Exploitation of the model.

To finish model validation, a policy sensitivity analysis is presented, this consists of making changes in the hypotheses in order to reverse the impacts or convenience of a proposed policy. For example, in the case of the model for the evaluation prioritization of green projects, it is proposed to change the diagram under which an investment decisions are calculated (water and land), analyzing two possible scenarios.

In the first test model, to calculate the value of the variable Incentives for Green Projects, a greater weight is given to the variable Investment Decision Water keeping without changes the variable Investment Decision Water, a greater weight is given to the variable Investment Decision Land. Now, exploring extreme cases, a second test model is proposed, in which one of the variables could be Investment Decision Water or Investment

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Decision Land becomes zero, in order to observe the changes in the variables Water Use Optimization and Land Use Optimization.

When carrying out the sensitivity analysis before the policies of the diagrams in the first, second and third test model, it can be seen how when the weight varies in the variable Investment Decision Water or Investment Decision Land, for the first test model, it presents greater variability than the second and third test models (see figures 11,12,13,14).

If it is possible to establish the weights of the variables investment decision for which the maximization of the variable incentive for green projects is achieved, the dynamic flow of this system evolves without having to commute between investment and non-investment decisions, in this way, the variability in the decisions of the entities in charge of evaluating and prioritizing the projects for this community is reduced. Additionally, if we compare the variables Investment Decision Water and Investment Decision Land (weighted), with the variables Water Project Prioritization and Land Use Optimization, it is clearer that the parameters associated with these, that is, the citizen factors, are the ones that significantly affect the behavior of the system. So, sensitivity analysis efforts can be concentrated on them to get more out of the model.

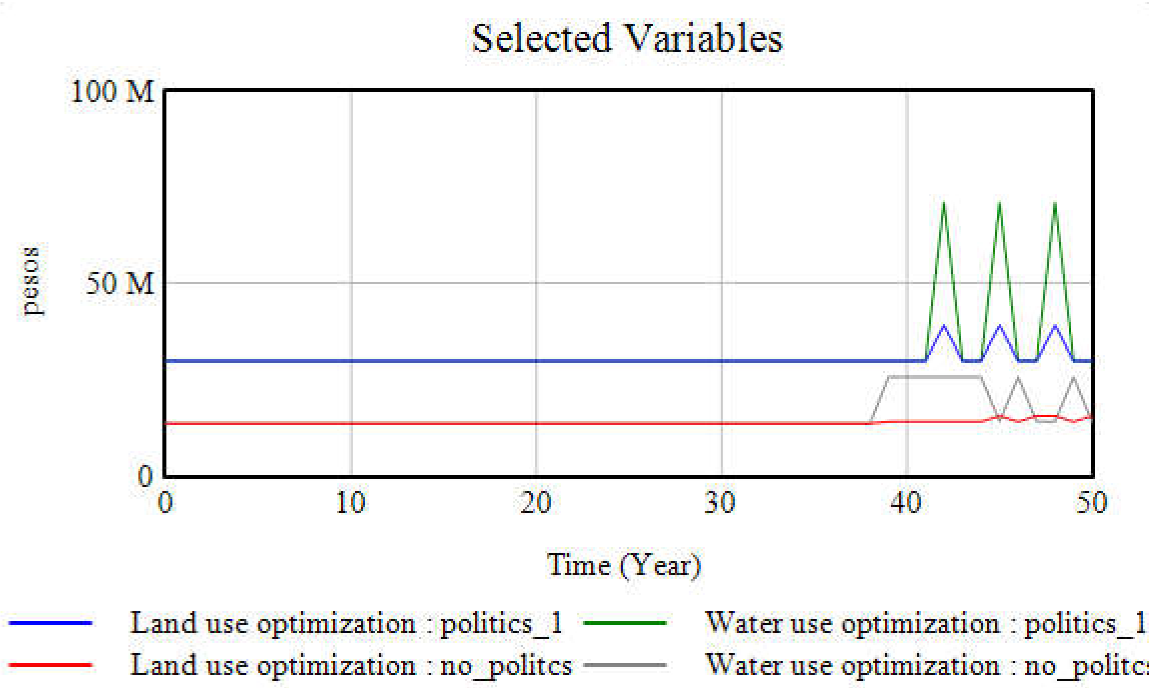

Figure 11. First test model – Variables Optimization of land use and Optimization of water use.

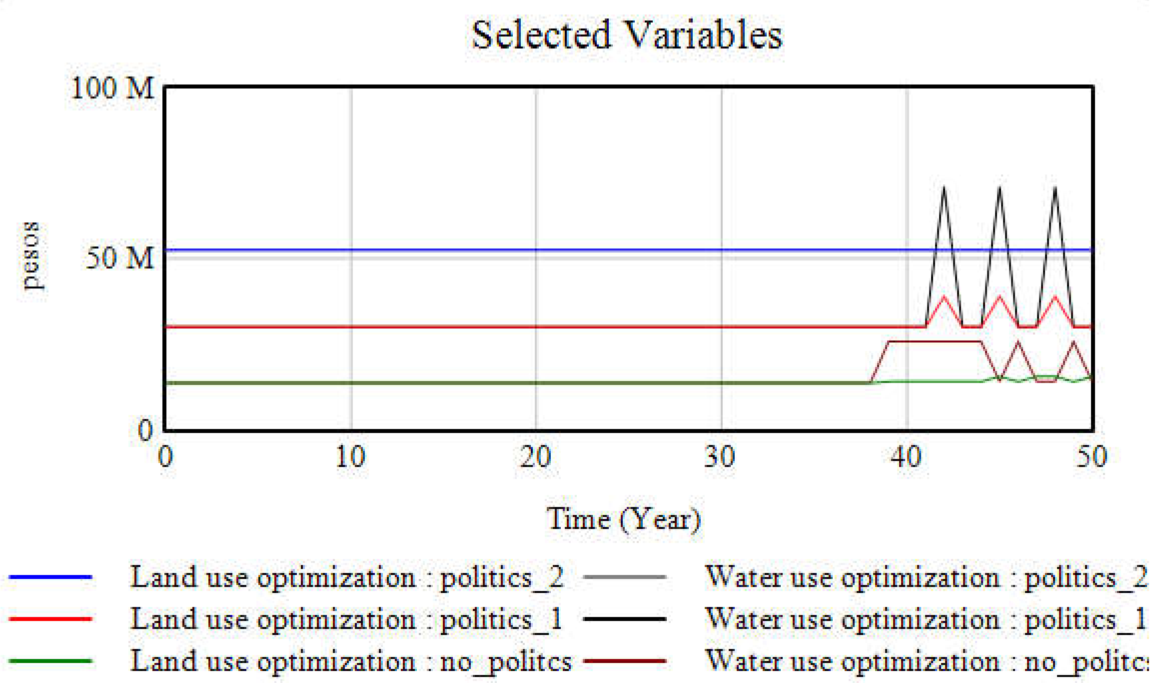

Figure 12. Second test model- Variables Optimization of land use and Optimization of water use.

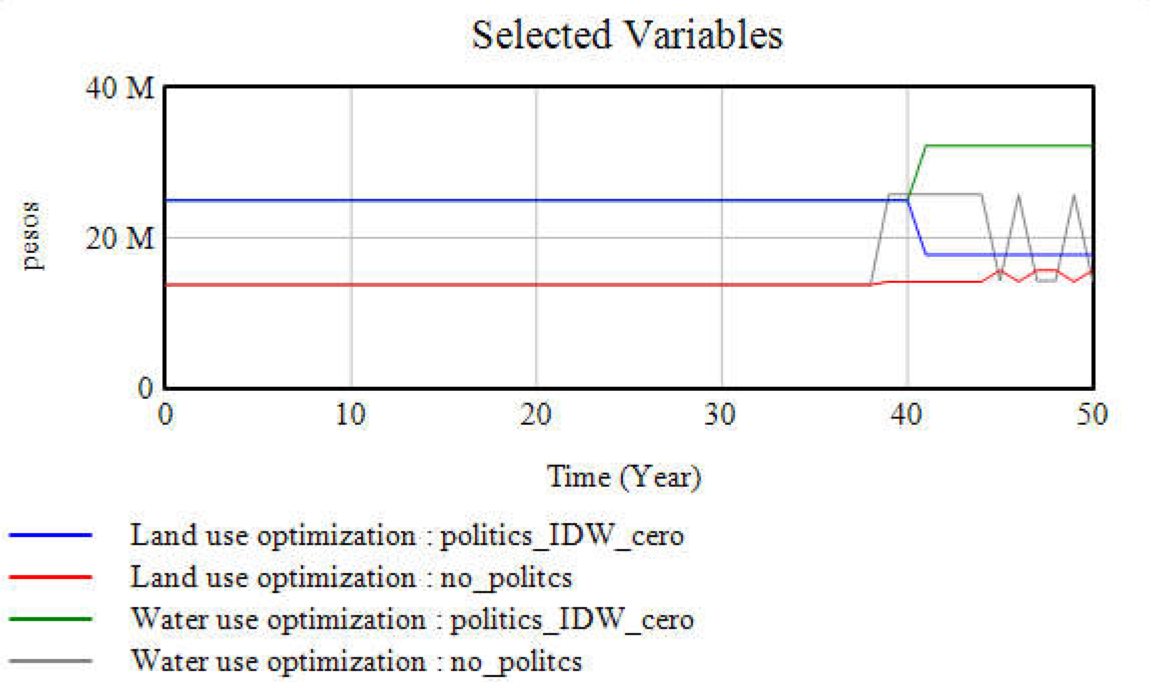

Figure 13. Third Test Model – Zero Water Investment Decision.

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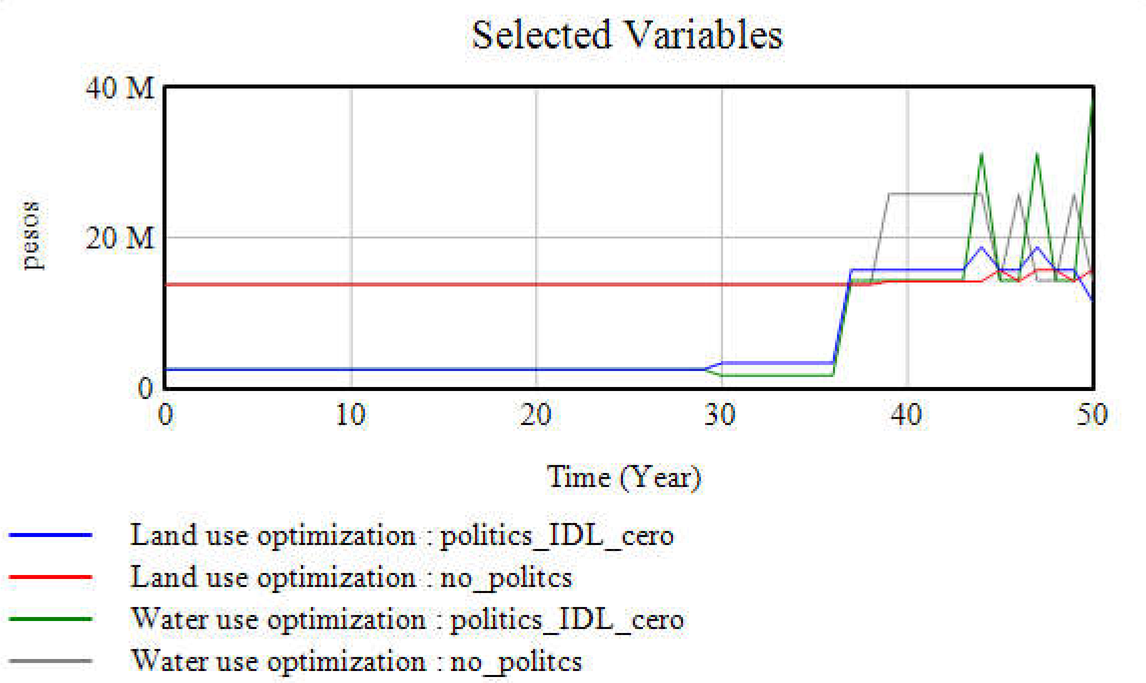

Figure 14. Third Test Model – Zero Water Investment Decision.

4. ANP network structure

The second phase of the proposed methodology corresponds to the evaluation and prioritization of projects through the multi-criteria decision method ANP (Network Analytical Process) [7], [36]–[40]. The ANP method allows to identify and consider mutual dependencies between the different evaluation criteria [13], [14], [41]. So, it is possible to structure a cluster and node network and, therefore, define the interrelationships that occur between them [42], [43]. The general structure of a network ANP is composed of source nodes and destination nodes (drain), these are determined when the paths of influence are established [15], [44]. The connections between nodes and elements can occur either through feedback to components of other elements by ringlets to the same components [12], [42], [45], [46]. Due to the large number of interdependencies and interactions in the proposed System Dynamics model, likewise, the impossibility of structuring it hierarchically, we have decided to use the ANP method like the method for the evaluation and prioritization of the projects (alternatives). The creation of the structure of the ANP network, starting from the System Dynamics model, it was carried out in different steps.

The first step consisted in the identification, in the model in DS of the clusters that would make up the ANP structure. in this point we identified 6 clusters that corresponded to the social, environmental and economic dimensions in addition to the citizen factors and the government dimension, the ANP structure was completed with the cluster that belongs to the alternatives or projects to be evaluated and prioritized, as shown in Figure 15.

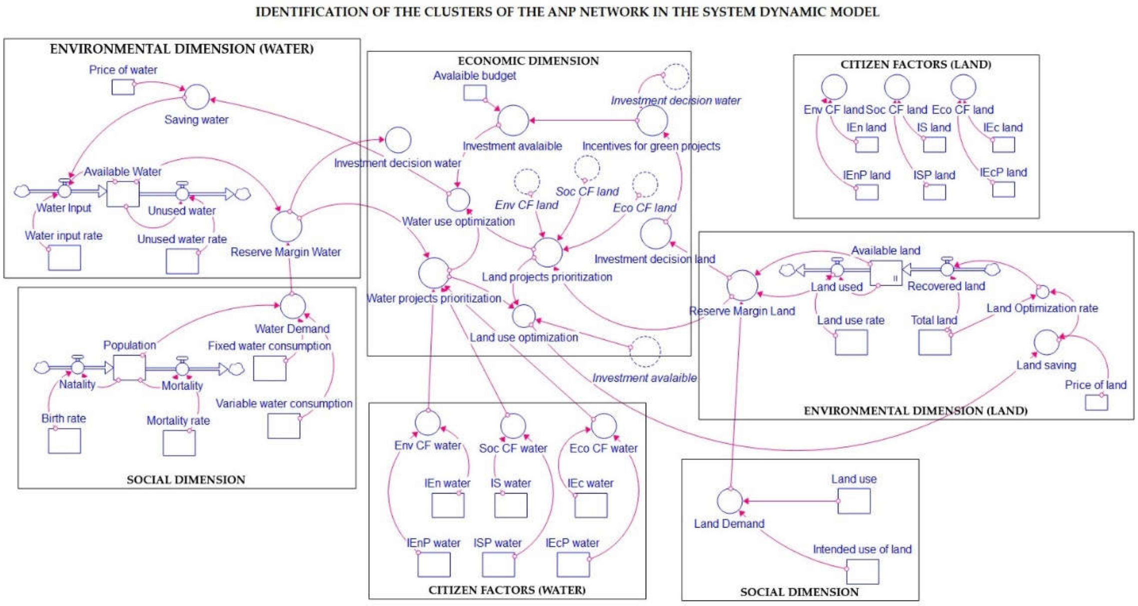

Figure 15. Identification of the clusters of the ANP network, in the System Dynamics model. Source: authors' own creation

The second step consisted in the identification of the nodes and elements that make up each cluster, in this way, those variables and parameters of the model that were found were established as elements inside each identified cluster in the before step. Likewise, the interconnections and dependency relationships were established according to the existing relationships in the model in DS. In the figure 16 we can see the complete structure of the ANP network

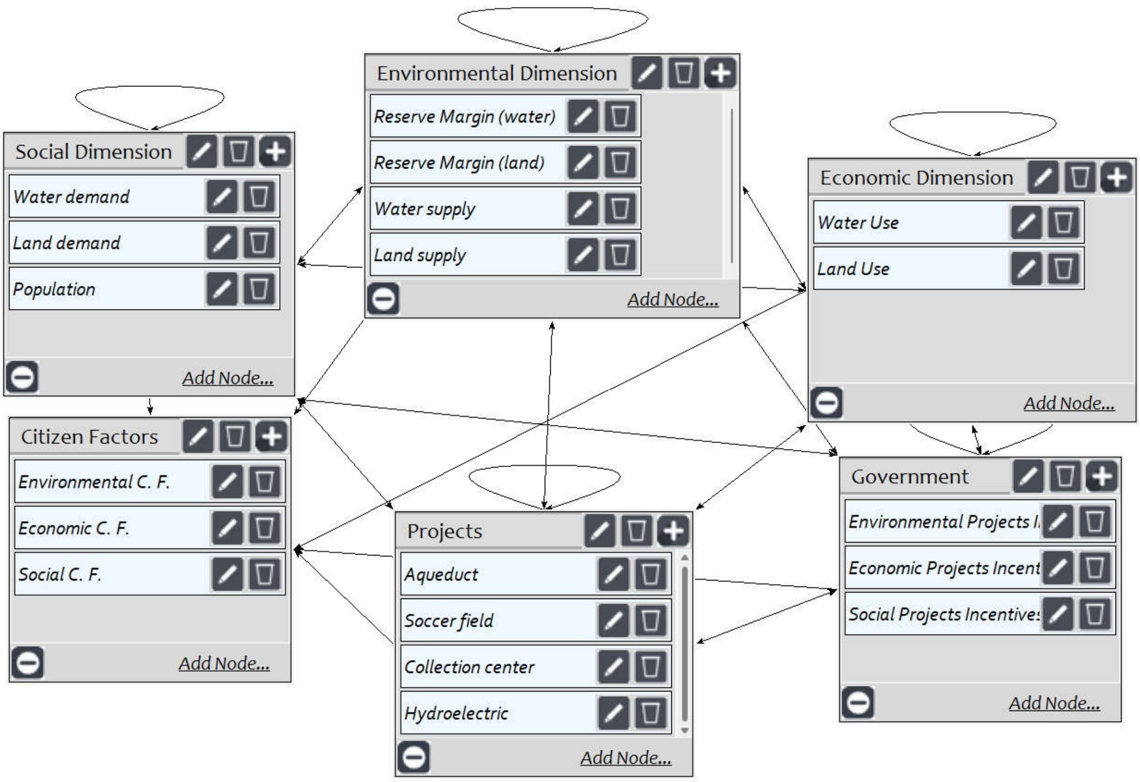

Figure 16. ANP network from the System Dynamics model.
Source: authors' own creation

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5. Study Case – California county (Fresno, Tolima)

The application of the proposed methodology was carried out through a case study in the county California, located in the Tolima department in Colombia (see figure 17), this zone. Therefore, belongs to the region of the downtown of the Magdalena region historically affected by the Colombian conflict until 2016 year in which the peace agreement was signed. The county extends over 150 hectares and is located on the eastern slope of the Central mountain range in an elevation of 1800 meters above the level of the sea and also belongs to the Guarinó river basin, an important tributary of the Magdalena river, one of the most important rivers of the country.

Figure 17. Geographic location of the California county, Fresno (Tolima).
Source: Tolima Governing [47].

5.1. Participatory Workshop (Participatory Rural Appraisal – PRA)

Through the participatory workshop carried out with the community of the county, it was possible to gather the necessary information to calibrate the balance model in System Dynamics, according to the variables and parameters proposed related to the supply and demand of water and land, likewise the citizen factors and support from local and national government, as well as other funding institutions. The workshop with the community was worked through the method called Participatory Rural Diagnosis [9], [48]–[56], the Table 1, shows the main findings, classified according to the dimension (clusters of the network ANP) to which they correspond (social, environmental, economic and government). Therefore, the citizen factors that were determined by the facilitating team of the workshop are presented after finishing it and likewise the alternatives, that is, the different projects to be evaluated and prioritized, which also belong to the 6 clusters of the network.

Table 1. PRA findings classified by dimension (ANP network cluster).

Identified Find	Dimension (ANP network cluster)	Used tool
Difficulties for arriving to the county	Socioeconomic	Venn Diagram
Small-scale agriculture (self-supply and external sale)	Socioeconomic	Venn Diagram
Main products: Cocoa, banana, avocado and coffee	Socioeconomic	Venn Diagram
Climate variety, many farmings and fertile lands	Economic	SWOT
No agro-tourism type projects are identified in the region	Economic and from the government	SWOT
Social connection	Social	SWOT
Abandonment by the state and local government	Social and from the government	Venn Diagram
The population of the county, most of them left the county due to the violence in the nearby regions	Social	Semi-structured dialogue
Diversity of thought and approach to the problems and needs of the community	Social	Semi-structured dialogue
Impossibility of taking adequate advantage of natural resources and the existing share capital due to the lack of institutional support in the development of high-impact projects and also lack of training for its inhabitants	Socioeconomic and from the government	Semi-structured dialogue
Soil Affectation (in Exchange of better productivity), by the use of pesticides and agrochemicals in crops.	Socioeconomic	Semi-structured dialogue
The community of California recognizes that technification in their crops can mean greater competitive capacity in the market, and a better position of their products with more profitable prizes	Socioeconomic	Semi-structured dialogue
The natural resource of water is widely accessible to the inhabitants, so it can be drunk directly from the springs and gorges of the zone	Environmental	Semi-structured dialogue
The community recognizes the problems that underlie the consumption of non-potable water in relation to the generation of diseases.	Social Ambiental	Venn Diagram
Industrialization processes or widespread growth of the main crops are not identified in the county, small-scale agricultural production being the main economic source, likewise the underemployment in the nearby counties	Economic	Venn Diagram
Project management or resources for productive projects in the county are not identified, which makes it difficult the improvement the physical, economic, natural and cultural conditions of the community.	Government	

5.2. Model calibration in System Dynamics

The calibration of the proposed model was made based on two main sources, the first corresponding to the participatory workshop developed with the inhabitants of the county California and the second corresponding to secondary sources such as the web pages of the mayor's office of the county and from foundations and private corporations that work in the region supporting the community through rural development projects, among others. As a result, Table 2 Calibration of the model in System Dynamics is presented below, in which the parameters, their value and the source from which it was taken are described. Likewise, the table shows the value assigned to each citizen factor and other assumptions that are taken into account within the System.

Table 2. Calibration of the model in System Dynamics.

Parameter	Description	Value	Units	Source
Water Input Rate	Amount of water provided by the different tributaries in the area per year	22	%	[47], [57]
Unused Water Rate	Amount of water not consumed or used per year	45	%	[47], [57]
Variable Consumption of Water	Amount of water consumed above the annual average	60	Cubic meters	[47], [57]
Fixed consumption of water	Amount of water consumed per year	130	Cubic meters	[47], [57]
Population	Number of inhabitants	200	people	[47], [57]
Price of Water	Value paid per m^3 of water	6000	Pesos	[47], [57]
Available budget	Amount of money available for investment	50	Million pesos	Model Assumption
Price of Land	Average value paid per hectare of land	150	Thousands pesos	[47], [57]
Land Use	Amount of land consumed per year	9000	hectares	[47], [57]
Intended use of land	Proportion of land (of the total) planned to be used for the following years	30	%	[47], [57]
Land Use Rate	Proportion of land (of the total) used each year	15	%	[47], [57]
Total Land	Total hectares of land (used and unused)	515	thousands of hectares	[47], [57]
FCS_{water}	Social Citizen Factor (Water)	20%	Dimensionless	Participatory Workshop
FCA_{water}	Environmental Citizen Factor (Water)	25%	Dimensionless	Participatory Workshop
FCE_{water}	Economic Citizen Factor (Water)	55%	Dimensionless	Participatory Workshop
FCS_{land}	Social citizen factor (Land)	10%	Dimensionless	Participatory Workshop
FCA_{land}	Environmental Citizen Factor (Land)	30%	Dimensionless	Participatory Workshop
FCE_{land}	Economic Citizen Factor (Land)	60%	Dimensionless	Participatory Workshop

5.3. Model evaluation for evaluation and prioritization

Coming up next, a series of simulations of the proposed model are presented, carried out using the Stella Architect software, in these the variation of the different variables of interest in the model can be observed, which were presented to the experts to be considered in the evaluation and prioritization of green projects. Once again, as was the case in the study carried out with this same methodology in the Pesebre county (Tame, Arauca) [6], confirms the hypothesis that was raised from the beginning, first of all, the reserve margins (water and land) of the figures 18 and 19, respectively, show how the change in the levels of supply and demand for water or land, represented in the defined margins, generate early alerts, which allow adequate control of investments.

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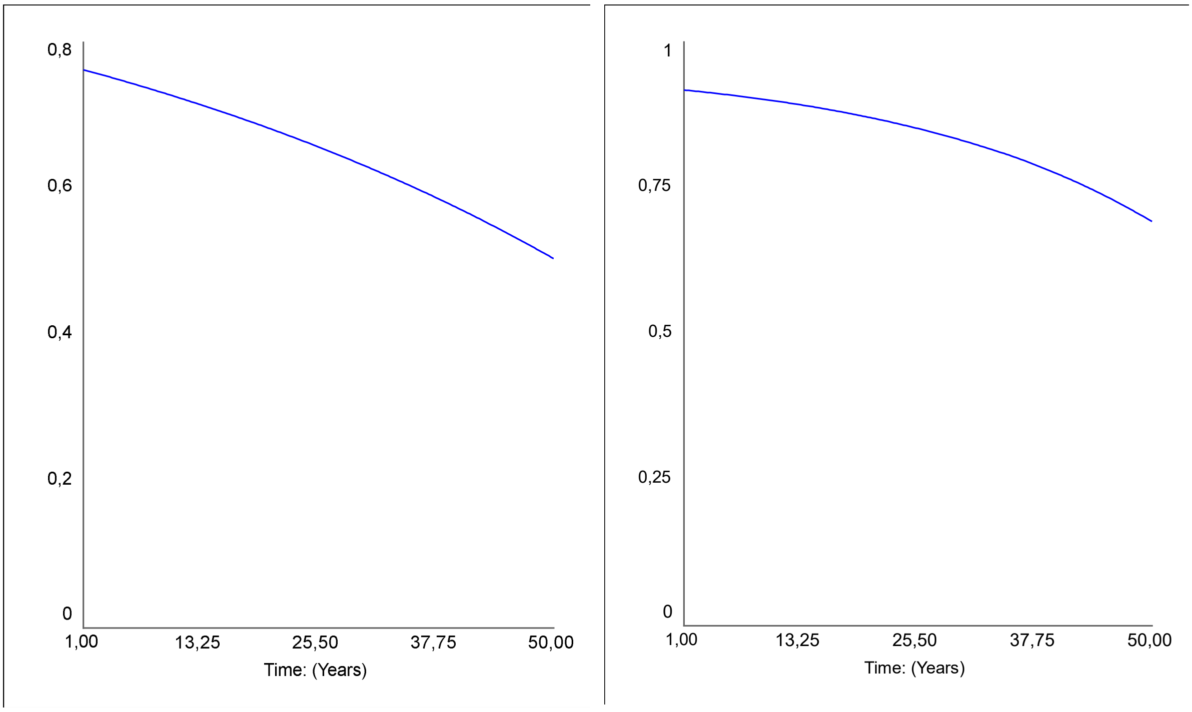
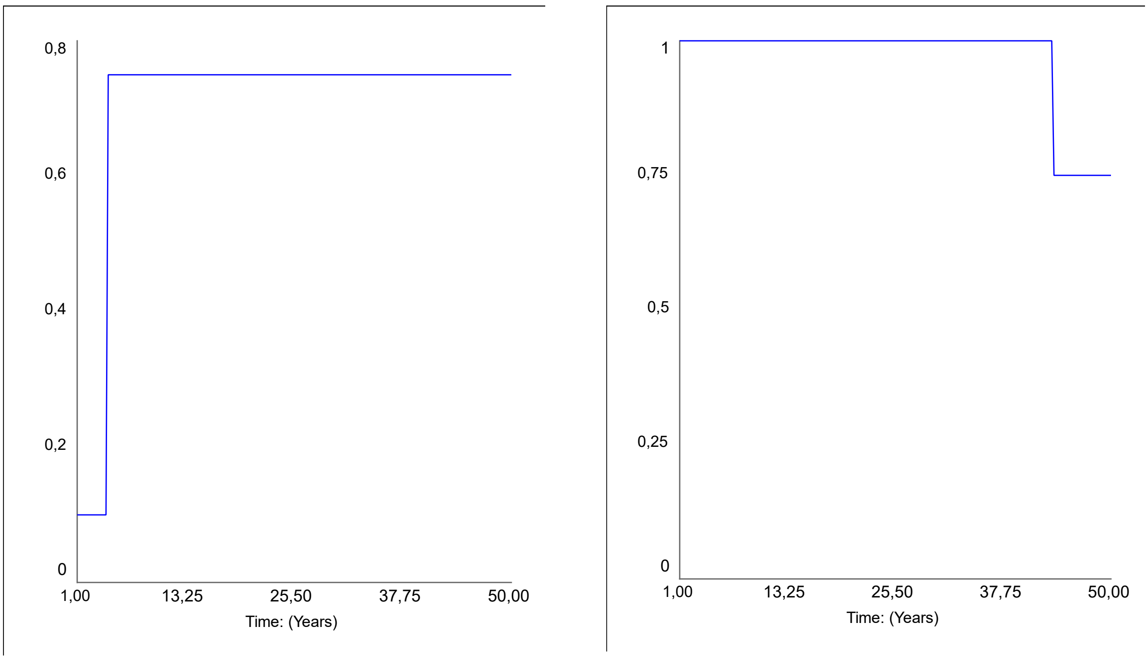


a. % Water Reserve Margin (water, year 0 to 50) **b**. % Land Reserve Margin

Figure 18. Simulation Reserve Margins Environmental Dimension.
Source: authors' own creation



a. Water Investment Decision (year 0 to 50) b. Land Investment Decision

Figure 19. Government dimension of the investment decision
Source: authors' own creation

In second place, we can see how the variables related with the prioritization and optimization of water and land resources, is also influenced by citizen factors, established through community participation. in accord with the figure 20, for the case of California county, it is evident how the community gives preference to water projects, that is, those in which their water sources can be used for a social purpose for their inhabitants.

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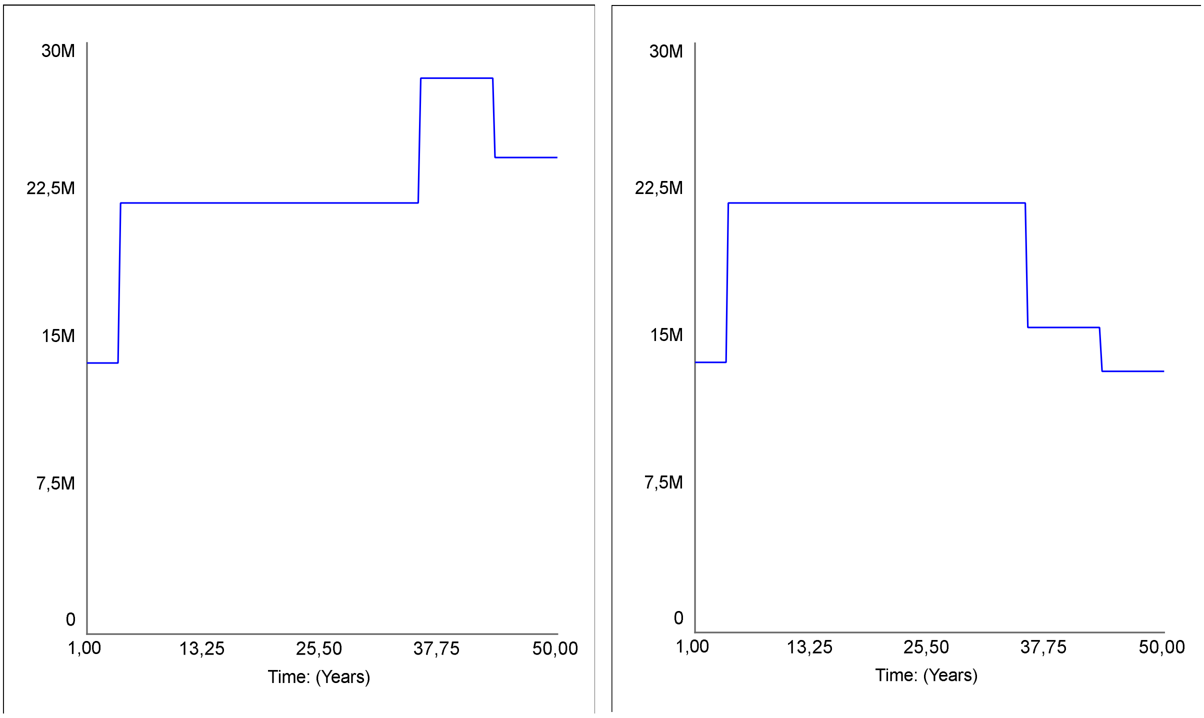

a. Water use optimization (year 0 to 50) **b**. Land use optimization (year 0 to 50)

Figure 20. Optimization of Resources Economic Dimension
Source: authors' own creation

5.4. Projects Evaluation and prioritization with ANP

Once the simulations carried out with the model in System Dynamics (DS), the second phase of the proposed methodology began, this consisted of the application of the Analytical network process (analytic network process-ANP). Having structured the ANP network, which was described in the chapter 3 of this document, the six dimensions proposed (social, environmental, economic, government, citizen factors and projects) likewise the elements (variables) likewise their corresponding elements (variables) were evaluated according to dependency relationships and defined feedback.

As mentioned in chapter 3, the ANP method is based on pairwise comparison [12], [58]–[63] to determine the priorities among the indicators or variables involved in the evaluation. the experts were asked that, according to the information presented from the model in System Dynamics, evaluate the relevance of the indicators considered according to the fundamental scale of Saaty [45], [64]–[66] (Table 3).

Table 3. Saaty Fundamental scale.

VALUE	DEFINITION	COMMENT
1	Equal Importance	Criterion A is just as important as Criterion B
3	Moderate importance	Experience and judgment slightly favor criterion A over criterion B.
5	Big importance	Experience and judgment strongly favor criterion A over criterion B
7	Very big importance	Criterion A is much more important than Criterion B.
9	Extreme importance	The greater importance of criterion A over B is beyond doubt.
2,4,6,8	Intermediate values between the previous ones, when it is necessary to qualify	

The first step of the evaluation refers to the pairwise comparisons between the clusters [41], [43], that is, among the six dimensions defined. Once the evaluations were compiled, it was possible to develop the evaluation matrix [63], [67]–[69], in which the

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numerical values represent the influence identified for the elements of the network. The second step after having established the priorities of the clusters was perform pairwise comparison for the nodes or elements or each cluster [39], [46], [70], [71]. Regarding to the evaluation of each cluster, the judgments were made taking into account the influences and interdependencies [12], [72], recognized in the network. For example, the figure 21 shows the pairwise comparison between "social dimension" and "economical dimension". In detail, the assigned value "4" refers to the fundamental scale of Saaty (Table 3). This means that the experts considered the "Social Dimension" more important than the "Economic Dimension".

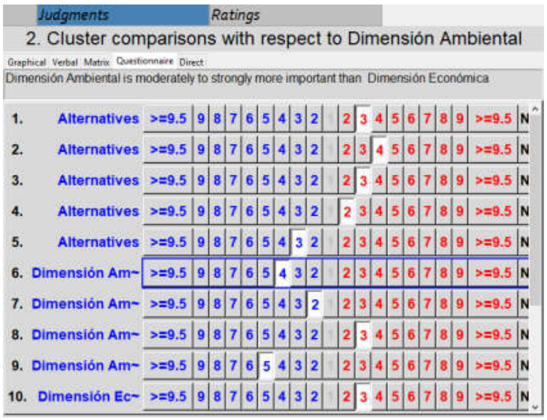

Figure 21. Environmental Dimension Vs. Economic Dimension.

The figure 22 shows the pairwise comparison between the nodes (elements) that belong to environmental dimension (cluster). In the same way that was done in the pairwise comparison by the clusters for the assignment of values the fundamental scale of Saaty was used in order to determine the importance of the different variables that compose it. In detail, the assigned values mean that, first, the "water reserve margin" is more important than "the land reserve margin" (value 3); second, the "water offer" is equally or moderately more important than "land offer" (value 2); and third, that the "water reserve margin" is moderately more important than the "land supply" (value 3). Great importance has been given to the "water reserve margin "in the county California. This is due in part to the fact that water is of vital importance in crops and thanks to the local aqueducts all the inhabitants can benefit from it, on the contrary, with the water or land, which are the private property of the inhabitants of the community or of companies that established their crops in the area, since the benefit is individual, as it is taken advantage of. In this context, it is possible to underline that the comparison by pairs has been carried out considering the characteristics of the area, and likewise the problems and needs of the California Community.

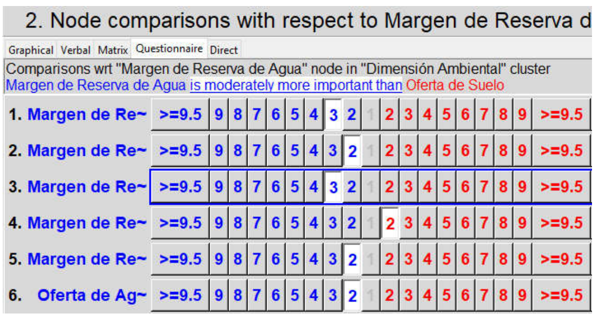

Figure 22. Comparison between nodes with the Saaty scale.

Once all the pairwise comparison matrices have been obtained for all the dimensions and the nodes, we can develop the unweighted supermatrix [12], [42], [60], in which all the priorities obtained through pairwise comparisons are detailed. Likewise, the supermatrix represents the relations between the nodes that compose the network. Now, to obtain the weighted supermatrix, it was necessary to multiply the unweighted matrix by the final vector of priorities [63], [64], [73]. It is important to highlight that, both for the construction of the ANP network and for the peer evaluations and the development and operation of the matrices, we used the super decisions software that was created by the foundation creative decisions [74].

6. Results and Optimization

How it was expressed in the previous sections, the ANP method was carried out at five different instants of time and taking into account the information obtained by means of the System Dynamics model for each moment of time in particular. In this way, it was possible to observe the various interpretations that the panel of experts can make when there are many data. At this point, the usefulness of a multicriteria process is highlighted like the ANP, through which it is possible to group different decisions about the same issue and establish a valid solution [75].

The figure 23 shows the individual results of the Network Analytical Process in each of the five moments in which it was determined to carry out the evaluation and prioritization. For this research, a twenty-year time horizon was used, being the year 0 (without intervention) the first year to be evaluated, followed by years five, ten, fifteen and twenty as the last year to be taken into account. This case corresponds to the California county in the Magdalena downtown region, a Colombian post-conflict period community.

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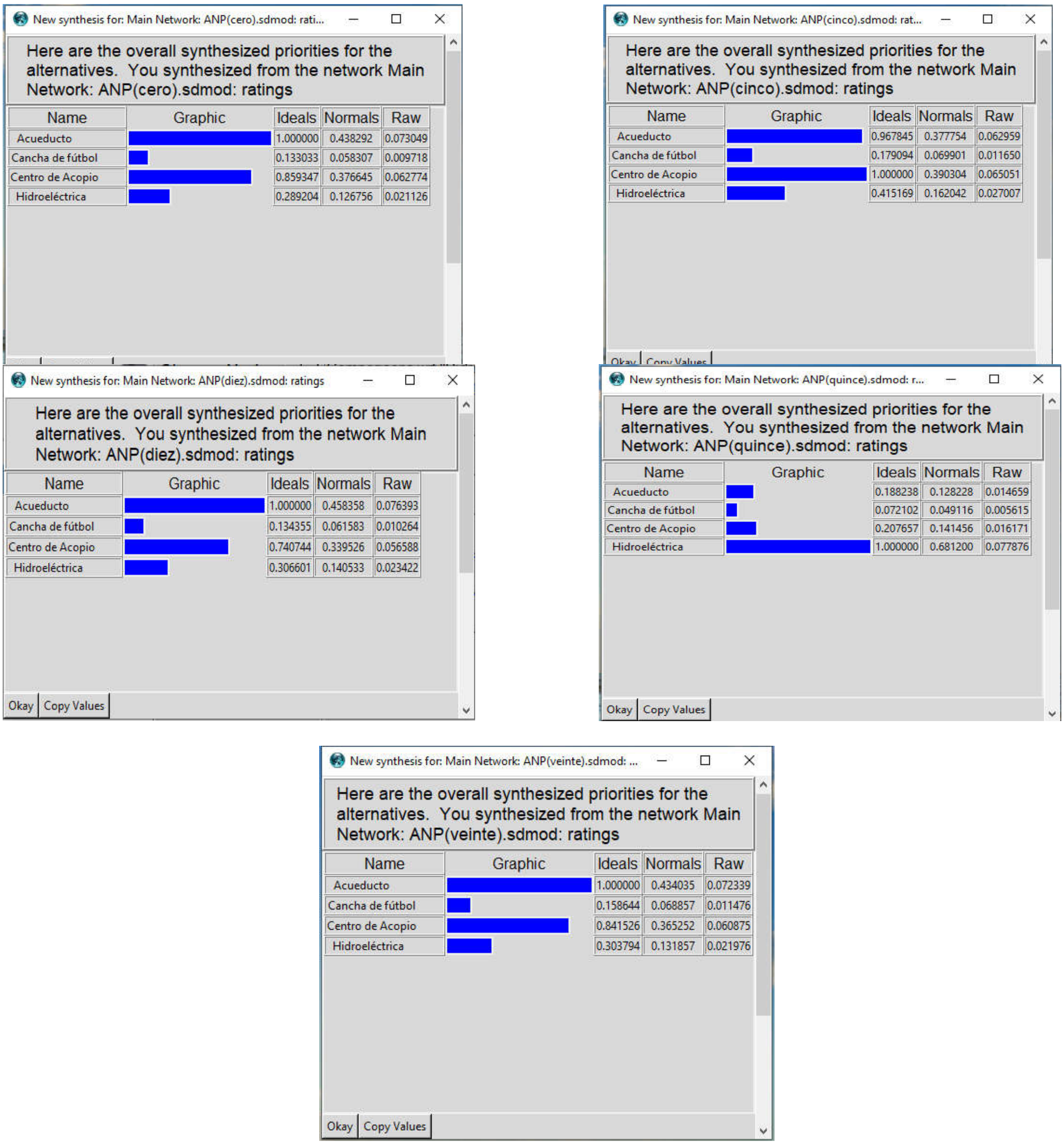

Figure 23. ANP evaluations (year 0 to 20).

However, the optimization process is based on the proposal described by Chichilinsky [76], to achieve sustainability, the basic idea is to exhibit a trade-off between preferences for the future and underlying natural resources (future supply and demand) and present preferences and consumption generated by utility criteria (current supply and demand). For this research, it was decided to give greater weight to the first ANP evaluations, 40% the first one (year 0), 30% the second (year 5), 15% the third (year 10), 10% the fourth (year 15) and 5% the last evaluation (year 20). The foregoing, taking into account that citizen factors express the most pressing needs and they are a Colombian post-conflict period community, its inhabitants expect a response in the short and medium term that improves their quality of life. The Table 4 shows the results of each ANP evaluation realized and its corresponding weight.

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Table 4. ANP evaluations and weights (year 0 to 20).

Project	Year 0	Weight 40%	Year five	Weight 30%	Year Ten	Weight 15%	Year fifteen	Weight 10%	Year Twenty	Weight 5%	Final Result
Aqueduct	0,438	0,175	0,377	0,113	0,458	0,068	0,128	0,012	0,434	0,021	**0,391**
Soccer Field	0,058	0,023	0,069	0,020	0,061	0,009	0,049	0,004	0,0688	0,003	**0,061**
Collection Center	0,376	0,150	0,390	0,117	0,339	0,050	0,141	0,014	0,3652	0,018	**0,351**
Hydroelectric	0,126	0,050	0,162	0,048	0,140	0,021	0,681	0,068	0,1318	0,006	**0,195**

7. Discussion

The proposed methodology for Evaluation and prioritization of green projects, presents the use of applied mathematics [36], [69], [77]–[79], in a field in which it has rarely been used, such as sustainable social development [80]–[84]. Likewise, it is observed how today it becomes important when taking into account the needs of the current world in which a balance is sought between social, environmental and economic development [85]–[87]. For this reason, the proposed methodology constitutes a contribution in this scientific field, in the effort to develop knowledge where different techniques are integrated that, regardless of any bias, help and improve decision-making processes on these issues, where it has certainly been seen how in some cases the influence of sectors or people alter the results and therefore the benefit to the community is also affected [88]–[95]. Therefore, represents a contribution in the integration of mathematics with the social and environmental aspects of the world.

Furthermore, in places where environmental conditions are often very favorable, in relation to the supply of natural resources such as water and land, but the social and economic conditions require a more detailed review. The proposed methodology, by integrating different methods and having a model that is calibrated according to participatory factors (citizen factors), ensures that the system includes not only the problems and needs, but also the expectations of the community, therefore, social learning processes take place [26], [84], [96]–[99], by means of which, it is possible to characterize the community [17], [87], [88], [100], [101], as well as the environment, the information that will be taken into account when evaluating and prioritizing, since when applying a multicriteria method, all the variables involved are considered, thus determining their true influence on the processal [102]–[105].

Although the processes of development and social learning are not usually linked to the application of mathematics, this research shows how this science, applied through mathematical modeling [106], [107], it can also contribute in this regard by indicating or highlighting aspects that must be taken into account when evaluating and prioritizing projects, which added or inserted in a multi-criteria decision-making process, which added or inserted in a multi-criteria decision-making process like the proposed ANP method, It can be of great help for decision makers, which results in better benefits and a better quality of life for the population [36], [38].

The above reasons mean that the integration achieved in the proposed methodology results in an innovative alternative that adapts to scenarios where the problems are usually complex as they involve society, even more, considering that these communities are in transition from the conflict to the post-conflict period, but its problems continue to exist and continue to require the attention of local and national governments and other institutions that work in the region. It is then observed how mathematics adapts to problems of a complex and real nature that not only allow to produce theory, also t is possible to put them into practice for the solution or the contribution to social development, especially of the communities of the post conflict period.

8. Conclusions

According to the main objective raised from the beginning, this research allowed us to determine the degree of affectation of investment decisions and investment incentives in green projects, when the citizen factors and the relationship of supply and demand of

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the natural resources of water and land are evaluated jointly, in the Colombian post-conflict period community.

Likewise, the relationship between social development and the scarcity of natural resources is remarkable, demonstrated in the supply and demand relationships of water and land. In this sense, it is observed how the inadequate use of resources also has adverse effects on the community, slowing down growth processes and deteriorates the quality of life of its inhabitants.

Furthermore, with the results of this investigation, the usefulness of mathematical models and decision-making methods is highlighted, in matters of social development that also involve environmental problems related to the appropriate use of natural resources, especially water and land. Likewise, at a time when climate change is directly related to the quality of life [17], [82], [108]–[110], the right decisions reflected in this case in the increase of the capacities of evaluation and prioritization of projects, they become a tool not only for local and national authorities but also for the communities themselves, with a view to undertaking projects that favor their environment and themselves.

We can see, therefore, how the component called "Citizen Factor", determined through participatory workshops with the community and included both in the System Dynamics model and in decision making, is the factor that, on the one hand, makes the problems and needs of the population visible, and, on the other hand, improves decision-making, since this factor establishes direct relationships between local knowledge (social, environmental and economic) and the potential benefits of the projects that undergo the evaluation and prioritization process.

Likewise, it is evidenced in variables such as the reserve margins (of water and land), available budget and the incentives of the green projects, the direct relationship with the social development of the community, as confirmed in the different ANP evaluations, carried out by the experts where they are indicated as those with more weight when prioritizing the projects.

However, it is observed how two different methods such as System Dynamics and the Analytical Network Process can be conveniently integrated and complemented, in order to make a more appropriate decision-making for the selection of green projects for a community. In this case, the modeling and simulation tools offered by the DS are used as data provided to experts who were able to make informed decisions according to peer review required inside the ANP method. In this way, citizen participation (participatory workshops and citizen factors) are linked in the proposed methodology, mathematical methods and models for the representation of a part of the real world (System Dynamics) and ANP multi-criteria decision-making method.

The fact of using an optimization method with partial results to obtain a single result, highlights the importance of citizen participation in the evaluation and prioritization processes, especially in the methodology proposed in this research, since, in the determination of citizen factors, activities that show not only "the urgent" are considered (present problems and needs that require immediate action), but "what is important" (needs and expectations that must be met in the future in the population). From the differentiation of the urgent and the important was how the weighting of the partial results of the ANP was achieved in the final evaluation.

On the other hand, it should be noted that the methodological proposal presented contributes to the reduction of biases in decision making, by involving different actors such as the community and experts, and by taking as a basis for decisions, information resulting from participatory modelling and peer review of criteria that is carried out by experts, and that allows to obtain a hierarchy within them and thus, more appropriate results to the population and the region.

Nevertheless, some limiting factors can affect the execution of the methodology, among them obtaining the active participation and trust of the community so the information obtained could be trustable and true. Likewise, the understanding of the scenarios presented to the experts and their relationship with the projects to be evaluated and prioritized, it constitutes an aspect to be treated with care, so that information is not lost or misinterpreted, which could alter decision-making.

Likewise, the inequality that is currently perceived in the countryside, prevents development processes from taking place properly, in the same way the lack of support and continuity of the projects by the governmental institutions, just as corruption causes the gap between the rural and the urban to be larger every day and that opportunities are lost to improve the quality of life of its inhabitants, jobs, health, education, the foregoing given, among other things, by the stigma that has been woven with respect to the rural field and the peasant of the conflict [6], [111].

Contrary to that, in the California county such circumstances have been an engine that drives daily for the search for change and improvement, the community is aware of its role in the territory and should not be alone in the search for well-being, especially if one takes into account that state support would consolidate the processes that are carried out.

Finally, this type of processes, like the one followed in this research, generates discussions about the concept of development and the need to understand that development is not linear nor can it be generalized, on the contrary, it is a process that is built with the transfer of the communities, their interests, conceptions, needs, views of the world and the natural, economic and cultural context. So, it is required to stop seeing communities as homogeneous societies and it is necessary to support them so that from their own knowledge build their own forms of development that allow achieving the integral well-being of their inhabitants and also of the territory. Additionally, it is evident how applied mathematics can contribute to improving evaluation and prioritization capacities related to the selection of green projects and, at the same time, contribute to the activation of social learning processes within the community, which finally translates into greater benefits and an increase in the quality of life of the population.

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