Modeling and simulation of a socioterritorial system: an exploratory analysis of the Southern Rural Territory of Sergipe, Brazil

Marcos Aurelio Santos da Silva
Brazilian Agricultural Research Corporation
Embrapa Tabuleiros Costeiros, Av. Beira Mar, 3250, Aracaju, Brazil
marcos.santos-silva@embrapa.br
http://www.embrapa.br/tabuleiros-costeiros

***Abstract*—This work presents an application of the Soclab framework on the task of modeling and simulation of a socioterritorial system. The aim of this work was to identify the general social structure and relevant social power relations in the Southern Rural Territory of Sergipe, Brazil. The results show that this territory is stable, the social actors search for cooperative partnership, but presents unbalanced structure and inequalities among social actors according to the capacity of action and power.**

Keywords: Sociology of Organized Action; social power; social relations

I. INTRODUCTION

Since 2003 the Ministry of Agrarian Development (MDA), by means of the Secretary of Territorial Development, has created the Rural Territories public policy. The aim is to promote the territorial development by leveraging the participation of society, mainly family farmers, in local decisions about investments in infrastructure; and improving social dynamism, cohesion, empowerment and engagement in sustainable activities. So, the goal of this territorial public policy is to, at the end, change the social behavior.

Each Rural Territory is a composition of a set of neighbors' municipalities that share: a strong presence of family farmers, a low demographic density (<80hab/km^2), a consolidated State's council for rural sustainability and an active civil society. In Brazil, it has created 239 Rural Territories, mainly located at the North and Northeast. In the Sergipe's state, there are four of them, including the Southern Rural Territory, created in 2007 [1].

To study and understand the social aspects of a territory [3] adopting the systemic approach and defining the socioterritorial system as an organization, without clear borders, ruled by a social system which presents weakness of the decision making process, but shows a strong interdependence among social actors. In fact, this systemic conceptualization emphasizes the central role of social aspects on territorial decision making process.

However, this systemic formulation does not show what social system best explains it, or how to transform it into an empirical study and how to formally model a real socioterritorial system. To overcome this problem, it has adopted the Sociology of Organized Action (SOA) social theory [4] and its formalization, the Soclab framework [5].

The main goal of this study was to explore analytically the power relations in the Southern Rural Territory of Sergipe, Brazil, using the SOA and the Soclab as theoretical and empirical references, respectively. Moreover, this analysis can be generalized to allow the application of the method presented here to other Rural Territories to support the assessment of other territorial public policies.

A brief review is presented in the next section and the Soclab framework in the third section. The fourth section is dedicated to the presentation of the case study, the Southern Rural Territory of Sergipe. The results and discussion is shown in the fifth section. Finally, the conclusions of this work are presented in the last section of this paper.

II. RELATED WORK

In general, the modeling and simulation of geographical constrained social aspects is treated as a socio-ecological system where the collective action coordination is analyzed as part of a coupled mechanism that includes the social actors, a technological system (e.g., irrigation system) and a natural resource (e.g., water) [6-7]. On the other hand, the socioterritorial system focus is on the governance of a regional area and the research is centered on how social actors create a stable social system by an interdependent network of shared tangible and intangible strategical resources [2-3].

The Sociology of Organized Action and the Soclab framework has been used to a variety of socioterritorial problems, such as: [8] assess the applicability and acceptability of a set of public policies on the watershed of Adour-Garonne, southeast of France. The aim was to reduce the water pollution from the agriculture activities by means of a social agreement about the usage of this natural resource; [5,9] evaluate four sociological hypotheses about

the social systems that ruled the watershed of the Touch river, France. They confirmed that the main social actor has enough power, capacity of action and influence to manage the changes in watershed control; [10] evaluate the power relations in the Corsica island council for watershed management. These applications can be considered as analysis of power relations on socioterritorial systems and have some general characteristics: they operate in the context of territorial multidisciplinary research; have exploratory and not conclusive character; social actors linked to agriculture are present in the governance of socioterritorial system.

III. THE SOCLAB FRAMEWORK

The Soclab framework was developed as a computational social analytical method based in the Sociology of Organized Action [5].

A. The Sociology of Organized Action

This social theory states that every organization, well-defined or not, can be described by its power relations among the social actors which compose it. These relations are mediated by "uncertainty zones" or resources, using the Soclab terminology, which are controlled by one social actor and needed by others. The SOA defines the power as the possibility for some individual or groups to act over individuals or groups.

The SOA analyzes the social system as an organization and assumes some hypothesis: the organization is a social construct that depends on their own internal activity; each social actor will have a degree of freedom, worth enough to allow him to achieve his goals; the social actors' strategies are based on the control of access to at least one resource; the relations of control and dependence creates an interdependent social network that stabilizes the organization.

According to the SOA the social game goes by a Concrete Action System (CAS) that structure the social behavior [4]. The CAS defines a social system as a set of social actors, uncertainty zones (resources) and a set of social actors' strategies. The social actor, in the CAS, is a rational agent which is always trying to achieve their own goals that are defined by historical context. The focus of the CAS is the local action (actors' action) that rules the emergency of the stability of the system.

B. The Soclab meta-model

The Fig. 1 shows the two main classes, Resource and Social Actor, of the Soclab's meta-model of the CAS which are linked with each other by two relational classes, Control and Dependence. The social actor has four properties (action capacity, power, cooperative power and satisfaction) and can "act", that means change the value of the state of the resource that he controls. The relations of control and dependence has two properties (stake and impact) and one effect function that model the effect of the resource over the social actor.

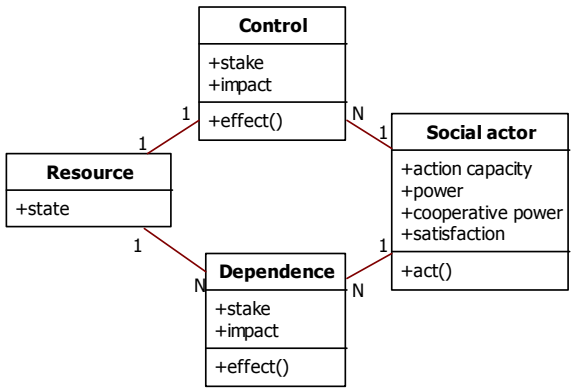


Figure 1. Soclab metamodel. Source: adapted from [5] and elaborated by the author.

C. Notation and terminology

Formally, the Soclab defines a CAS as:

- A set A of N social actors, A = $\{\alpha_1,\alpha_2,...,\alpha_N\}$.
- A set R of M resources, R = $\{r_1,r_2,...,r_M\}$, represented by the vector $r = [\lambda_1, \lambda_2,..., \lambda_M]^T$, where λ_m represents the level of access to the resource r_m, $\lambda_m \in$ [-10, 10]. If λ_m value are around -10 it means a strong difficult to access it, while if the value is around zero it means neutrality and around 10 denotes a complete access to it.
- The relations of control: A → R, if $\alpha_n \rightarrow r_m$ then α_n controls r_m, hence, the value λ_m of the resource r_m is controlled by α_n. Each social actor controls at least one resource.
- The relations of dependence: A ← R, if $\alpha_n \leftarrow r_m$, then α_n depends on r_m.
- A stake matrix **S**, where $s_{mn} \in$ [0, 10] and $\Sigma s_{m.} = 10$. For each relation between a social actor α_n and a resource r_m must be setted a stake s_{mn} so that the sum of all stakes for one social actor must be 10.
- A set E of F effect functions, E = $\{e_1, e_2, \ldots, e_F\}$, all functions has its domain and image in [-10,10]. The effect function will compute the effect of the resource r_m over the social actor α_n which controls or depends on it. The impact I_{mn} of this resource over this actor is defined as $I_{mn} = e_f(\lambda_m)s_{mn}$.
- A solidarity matrix $\mathbf{W_{NxN}}$ where $w_{ij} \in$ [-1, 1], $\Sigma w_{.j} = 1$.

Using this formalization it is possible to define four functions to calculate the social actor's action capacity C_n, power P_n, cooperative power P_n^c and satisfaction S_n. If the solidarities are not considered **W** = diag(1) and $S_n = C_n$.

$$C_n = \sum_{\forall r_m \in R | a_n \leftarrow r_m} I_{mn} \quad (1)$$

$$P_n = \sum_{\forall r_m \in R | a_n \to r_m} I_{mn} \quad (2)$$

$$P_n^c = \sum_{\forall r_m \in R | a_n \to r_m \wedge I_{mn} > 0} I_{mn} \quad (3)$$

$$S_n = \sum_{j=1}^{N} C_n w_{nj} \quad (4)$$

D. Modeling

Social actors and their resources may be mapped using any sociological approach or simply the expertise of the modeler. However, to collect data in a more structured way, considering the Soclab framework, [5] suggests the use of a simple form with basic questions, listed below, that will mainly help the design of the effect functions.

- What are the resources that you need to achieve your goals?
- Who controls these resources?
- How important they are to your activity? [0,10]
- Describes your behavior for a restrict access to these resources
- What is the effect of the previous situation on you? [-10,0]
- Describes your behavior for an unrestricted access to these resources
- What is the effect of the previous situation on you? [0,10]
- Describes your behavior for a neutral access to these resources
- What is the effect of the previous situation on you? [-10,10]
- What is the business as usual situation related to the level of access to these resources?
- What is the effect of the previous situation on you? [-10,10]

In this phase you must identify the set of social actors and resources, distribute the stakes of social actors, construct the solidarity matrix, if it applies, and design the effect functions. To compute the effect of a resource on a social actor, for every social actor-resource relationship, it is necessary to define one function which the domain, in the range [-10, 10], is the level of access to the resource and the image, also in the range [-10, 10], corresponds to the effect of the resource over the social actor. In fact, the curve of the effect function can take any form, however, for simplifying the interpretation of the results it may be restricted to linear, parabolic or sigmoidal curves.

E. Simulating

The Soclab framework considers the social game as a cooperative game where the social actor tries to maximize their satisfaction, if the solidarities are considered or action capacity otherwise. The algorithm is based on a reinforcement self-learning strategy and can be summarized as follows [11]:

```
defines actor.rule {
  Sit : vector // a vector of e_f(λ_m) for all resources that he depends
  Act: vector // Act_i ∈ [-1.8; -0.2] ∪ [0.2; 1.8]
              // Act_i represents the change in the resource state
              // i that the social actor controls
  Force : real // represents the efficiency of the rule }

function select.action(t, situation_αn) {
  Update.Force.appliedRules(t-1,t-2)// Reinforcement
  if Select.applicableRules(t, situation_αn) ==
                                        "Okay" then
     SA ← Select.Randomicaly.OneSelectedRule()
  else
     SA ← Create.New.Rule(t)
return SA.Act}

main {
t ← 0   // Discrete time step initialization
repeat
     for each social actor α_n do
       situation_αn ← perception(t, α_n)
       action_αn ← select.action(t, situation_αn)
     for each resource r_m do
       change.state(t, r_m, action_αn → rm )
     t ← t + 1
until no changes required or exceed time limit}
```

The function perception calculates the S_n for all resources that the social actor depends on. The function select.action selects the action to be performed by the social actor based on a list of rules created during the simulation process (Fig. 2). The procedure change state changes in the status of each resource according to the selected action.

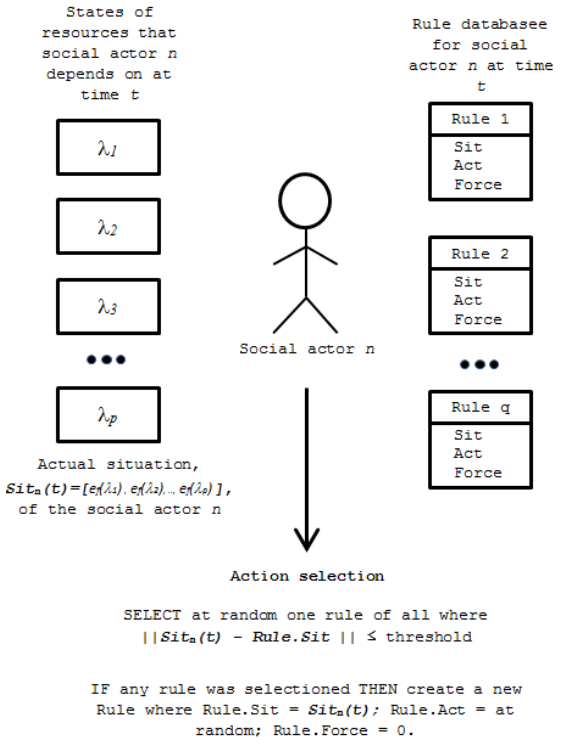


Figure 2. Schema to illustrate the selection of action by the social actor. Source: elaborated by the author.

The Soclab software has a module for sensitivity analysis of the psycho-cognitive parameters that differentiate each

social actor in terms of the level of: solutions' exploration during simulations; how they will consider the past (memory); the threshold definition to evaluate the actual situation, according to the situation of the rules, also during the simulation; and how the social actor reinforces a successful role in the future steps. However, these parameters were not evaluated in this work.

All the experiments were taken using the Soclab software available at http://sourceforge.net/projects/soclab/.

IV. Case study: The Southern Rural Territory of Sergipe

The Fig. 3 shows the Southern Rural Territory of Sergipe (SRTS) which includes twelve municipalities (Itaporanga d'Ajuda, Salgado, Estância, Boquim, Arauá, Pedrinhas, Santa Luzia do Itanhy, Indiaroba, Umbaúba, Cristinápolis, Tomar do Geru and Itabianinha) from the state of Sergipe, Brazil [1]. It comprises 3,950.90 km^2 with a total population of 278 955 inhabitants, of which 44% reside in rural areas. It has 1,256 settled families and 20,599 establishments attached to the familiar agriculture. The agriculture and livestock are the main rural economic activities in this region with a significant participation of family farmers. It has observed a strong presence of permanent crops such as orange and coconut.

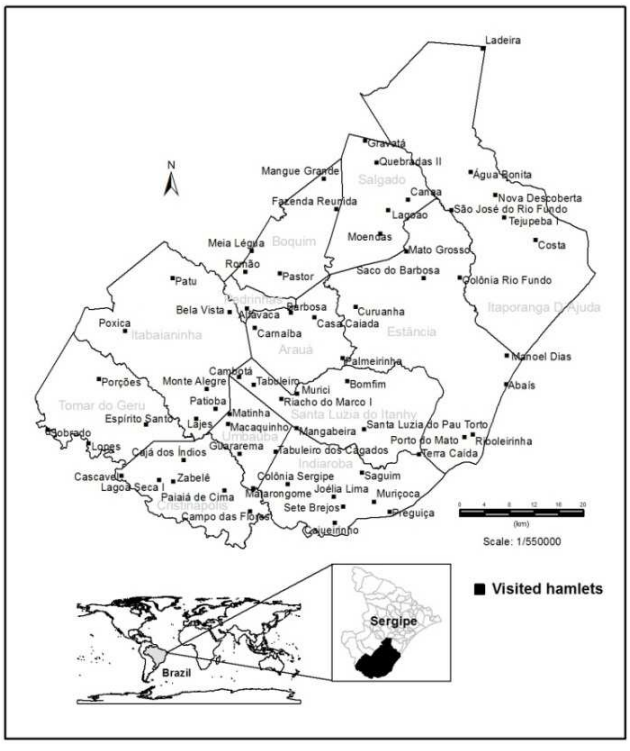


Figure 3. The Southern Rural Territory of Sergipe. Source: adapted from [3] and elaborated by the Laboratory of Applied Geotechnologies from the Embrapa Coastal Tablelands.

In 2007 the MDA created the SRTS and a Council to rule it. This Council is composed of representatives from institutions tied to the familiar agriculture and his main goal is to design a plan for a sustainable territorial development. Despite some initiatives, this plan is not ready until now. In fact, considering the entire region, it was observed a weak social mobilization around the territorial Council and a strong sectoral inclination that lead the Council to treat separately the economy, the environment and other social initiatives.

V. Results and discussion

The study of the SRTS was performed by interviews, questionnaires and documental analysis during 2009-2010 [3]. The researchers chosen at random 65 rural hamlets to apply semi-structured questionnaries (Fig. 3). The first social actors and resources draft appeared in [3] and showed that some social actors, associated with the environmental conservation and to the economic activities, does not take part in the SRTS Council and that there was not a strong engagement among the communitarian rural associations and this Council. So, it was decided to model only the relations among social actors that were strongly tied with the SRTS Council. The solidarities were not considered, so $S_n = C_n$.

A. The model

To model the SRTS it has assumed two hypotheses: the behavior of social actors which are associated with the same group is homogeneous enough to allow us to represent it by only one social actor (associations, unions, majors, banks and municipal councils); it is possible to identify informal relations among social actors by yours institutional resources. The Table I shows all relevant social actors from the SRTS that are tied to the territorial Council and the resources controlled by them.

One of the most important social actors is the Emdagro, it controls a wide range of strategic resources (e.g., rural assistance and extension, technological diffusion) and has offices in all municipalities. The Emdagro is the only social actor which, in our model, controls two resources and this symbolizes the force of it. The most valuable resource is the rural space, controlled by the Asscomprod. Almost every social actor needs to access this resource.

The Table II shows the stakes of the social actors distributed to all resources. From these data it is observed that the socioterritorial systems is composed of actors which expect a cooperative social game because each one puts more stakes on resources controlled by others. As expected, Embrapa is the least dependent on the others. As an agrarian research organization with a limited capacity to technology diffusion its stakes were put on resources controlled by the Emdagro and in the rural space controlled by the Asscomprod.

The effect functions are illustrated in Table III. It is possible to analyze the effect of each resource on social actors taking a look per row, or analyze the effect of each resource on one social actor looking at the columns. For example, the effect of the resource "sociopolitical mobilization" is positive and increase linearly for almost all social actors when the access to it is reduced (negative). It

suggests that social demobilization can be an opportunity to impose your ideologies, ideas and thinkings to the others. otherwise if people are completely politically mobilized it may be good only for whom is engaged with the Union.

The effect of the "technical assistance and rural extension" on Emdagro is completely negative for a negative access to it, and it increases until some threshold where after that this social actor lost its capacity to attend the demand. It was observed that for some resources the effect on social actors tied to the State's public policies are contrary to the effects on social actors tied with municipal's political forces. It's the case of the "consulting on SD", "technical assistance and rural extension", "plan for municipal development" and "public policies for municipal's sustainable development".

B. The simulations

It has used default values for all psycho-cognitive parameters in the Soclab software. It has performed 100 simulations with 200000 steps each one at most. The algorithm reached the stability in 98% simulations with an average steps of 73883. All the results presented in this section consider only the values of variables from converged simulations.

The Table IV shows the average values and the standard deviations for action capacity and states for all social actors and resources. The Banco, the Pronese and Embrapa have high scores for action capacity (55.09, 49.30 and 41.23, respectively), this means that they have more chances to cooperate with others. The Sindicato is the social actor with the worst action capacity (16.70) and with a great standard deviation (7.22), this suggests that the Sindicato is somehow locked and with a limited space of action. Despite of the centrality and importance of the Emdagro it has a small action capacity (20.62) with a great standard deviation (6.00), so the two resources controlled by this actor does not give him the necessary capacity due to its opposition to others actors and its limitation to attend the demand for rural assistance. Analogically, the same occurs to the Prefeitura and to the Condem_cmds.

Only two resources presented a greater access to it after converging simulations, "consulting on SD" controlled by the Pronese and "rural space" controlled by the Asscomprod. In fact, they are key social actors that shares without restriction their resources. Some resources' states stabilized in the neutral region, around zero, this means that this socioterritorial system shows some kind of indifference toward local initiatives (plan for municipal development, public policies for municipal's sustainable development) and to the technological developments.

Table V shows the action capacity for each social actor per row and the contribution of each actor to the total amount of C_n. For example, Embrapa's total action capacity is equal to 42.5 that is the sum of 30.4,8.8 and 3.3. At the bottom of the table we have two rows with the power and cooperative power for each social actor (column). The most powerful social actors are the Asscomprod (92.6), the Emdagro (67.4) and the Sindicato (58), this means that they control resources which finishes the simulation process in a position that maximizes the impact on each of these social actors. In fact, the Asscomprod controls a key resource, "rural space". Embrapa (5), the Prefeitura (5.7) and the Condem_cmds (6.7) have the worst values for the variable power.

The cooperative power follows the analysis of the power. The Asscomprod (93.2), the Emdagro (67.4), the Sindicato (58) and the Pronese (53.4) have the highest values for the cooperative power variable. While Embrapa (10.3), the Condem_Cdms (10.6) and the Prefeitura (13.7) have the worst values.

C. Scenarios

It has evaluated two scenarios, as an exploratory exercise, to check what happens if the range of accessibility to the resource technological knowledge change from [-5,5] to [-5,9] and what occurs if the effect function of the relation between the Sindicato and the sociopolitical mobilization resource change from quadratic to a positive linear function. In the first scenario, nothing happens and it is due to a lack of engagement of Embrapa (resource's owner) in relation to the others, so it is expected a little perturbation in the total system even for great changes in the access to the resource controlled by Embrapa. For the second scenario, the socioterritorial system converge in 77% of the simulations, so it gains some instability and the final results for some variables also changes. The average C_n (standard deviation) for the Prefeitura dropped from 32.12 (5.00) to 18.54 (7.16), the average state for sociopolitical mobilization increased from -8.87 (0.21) to -3.86 (4.30), and the P_n of the Sindicato dropped from 58 to 18.2. This all means that the Prefeitura was the main impacted by the change in the Sindicato behavior, that the stabilization is reached for a more neutral access to the resource "sociopolitical mobilization" and that the Sindicato lost part of his power.

D. Validation

The validation process was performed by interviews with researchers directly involved with the Rural Territory and with the actual responsible for the Council coordination. These results were presented to them, which could confirm or not according to their own experience.

The interviewers confirmed all the results from this research and made some observations that clarifies some conclusions of this study performed between 2009 and 2010: the opposition between local forces (major and councils for economic development) and state's interests is a matter of apathy of the former; The Emdagro had a great visibility in the territory but its participation at the territorial Council is decreasing in later years, as well as its capacity to 'delivery' their main resources; the flow of financial resources from the World Bank during the research time (2009-2010) projected the Pronese as a important protagonist in the SRTS, but it is not observed anymore nowadays; there are some conflicts among other territorial public policies (e.g., Identity's Territories and Citzenship's Territories); the public policies for territorial financial support is greatly top-down. so this diminishes the force of bottom-up initiatives and prevents a cooperative social game.

In sum, the validation process showed that the results are reasonable and that the entire process increased the knowledge about this Rural Territory.

E. Territorial public policy assessment

Evidently, a comprehensive assessment of a territorial public policy involves a huge amount of effort in many directions. The Soclab framework showed to be suitable to systematize information about social power relations and, hence, create a baseline to permit comparisons with future social configurations of the same Rural Territory.

Using the model and the simulation results it is also possible to judge the actual situation and make suggestions about the arrangement of social actors. As observed, the Southern Rural Territory of Sergipe is a stable organization, but has some problems with representation, some resources with limited access (e.g., "financial resources", "technological knowledge") and a power/action capacity distribution imbalance. So, one can suggest the addition of new social actors to the Council and a change in the internal procedures of it to equilibrate the social game.

VI. CONCLUSION

The overall process of modeling and simulation of the power relations of a socioterritorial system improved our understanding about the general social behavior of the Southern Rural Territory of Sergipe. The Soclab framework showed to be an insightful tool for learning about social interdependencies. It is also simple to understand, to use and could be applied in a real world problem.

Due to the exponential complexity of the simulation algorithm, it is not possible to use the Soclab software for medium or large social networks. The design of the effect functions can be challenging if the modeler does not know deeply the studied social system.

Future works could explore other social theories as support for modeling and simulation and also use more strongly the spatial dependence among social actors and their resources to map the results of the simulation into a geographical space.

ACKNOWLEDGMENT

This research was performed with support from the Brazilian Agricultural Research Corporation (project no. 03.09.01.004).

REFERENCES

[1] E.R. Siqueira; M.A.S. Silva; A.G. Aragão, "O território rural centro-sul de Sergipe", 1. ed. Aracaju: Embrapa Tabuleiros Costeiros, 2010. v. 1. 223p.

[2] M.A.S. Silva; C. Sibertin-Blanc; B. Gaudou. Modélisation des processus sociaux pour le développement rural durable : le territoire comme système complexe d acteurs. In: Colloque National - Ecologisation des politiques et des pratiques agricoles, 2011, L'Isle sur la Sorgue. Colloque National - Ecologisation des politiques et des pratiques agricoles. Avignon: INRA PACA, 2011.

[3] M.A.S. Silva; S.S. Medeiros; M.G.L. Manos and E.R. Siqueira, "Modelagem social computacional como instrumento de análise de sistemas sociais territoriais complexos: o caso do Território Sul Sergipano, Brasil", Campo - Território, v. 9, p. 55-85, 2014.

[4] M. Crozier & E. Friedberg, "L'acteur et le système", Seuil : Paris, 1977.

[5] C. Sibertin-Blanc; P. Roggero; F. Adreit; B. Baldet; P. Chapron; J. El-Gemayel; M. Maillard; S. Sandri. "Soclab: a framework for the modeling, simulation and analysis of power in social organizations", Journal of Artificial Societies and Social Simulation, v. 16, n. 4, 2013.

[6] A.R. Poteete; M.A. Janssen & E. Ostrom. Working Together:Collective Action, the Commons, and Multiple Methods in Practice. Princeton University Press: Princeton, 2010.

[7] M. Étienne. La modélisation d'accompagnement: une démarche participative en appui au développement durable. Quae: Versailles, 2010.

[8] F. Adreit; P. Roggero; C. Sibertin-Blanc; C. Vautier. Prendre en compte la dimension sociale dans un projet de développement durable : fondements et utilisation du système soclab. Systèmes d'Information et de Décision pour l'Environnement, SIDE'09, 5-14, Toulouse, 26 mai, 2009.

[9] B. Baldet. Positionnements stratégiques autour du risque d'inondation : modélisation et simulation du cas de la vallée du Touch en Haute-Garonne. Congrès de l'Association Française de Sociologie, 05 juillet 2011, Grenoble.

[10] M. Casula. Innovation politique et changement organisationnel dans la gestion de l'eau : la création du comité de Bassin de Corse, Congrès de l'Association Française de Sociologie, 05 juillet 2011, Grenoble.

[11] J. El-Gemayel, "Un modèle par apprentissage de la rationalité des acteurs sociaux", Dissertation, IRIT, Université de Toulouse 1 Capitole, 2013.

TABLE I. SOCIAL ACTORS AND THEIR RESOURCES. SOURCE: ELABORATED BY THE AUTHOR.

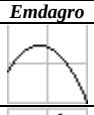
Social actor	***Social actor's description***	***Resource***	***Resource's description and accessibility***
Pronese	The Company for Sustainable Development of the State of Sergipe manages programs and activities in rural areas with a focus on poverty reduction, managing credit programs and preparation of environmental management plans.	Consulting on SD	Consulting on sustainable development public policies for rural areas by rural developing projects. In general, these projects are linked to funding sources, e.g., the World Bank, the Banco do Nordeste. Key stakeholders in this feature are the family farmers, the Emdagro and aligned municipalities with State's policies of agricultural development. There is no restriction to access this resource, so accessibility is in the range [-10,10].
Emdagro	The Agricultural Development Company of Sergipe. Works with the family farming and sustainable agriculture in the areas of technical assistance, research, regularization	Technical assistance and rural extension	One of its main features is the technical assistance and rural extension, especially for family or small farming properties in the region. The Embrapa, the Pronese, municipalities and family farmers themselves depend on that resource to achieve their own goals. However, the lack of structural capacity limit the access to it and prevents a greater commitment

	etc. The Emdagro is spatially distributed throughout the SRTS with offices in every municipality.		of Emdagro with their customers, so there is some restriction to access it [-8, 8].
		Technology diffusion	This feature directly concerns Embrapa which is a leading developer of agricultural technology. However, due to limited personnel there are restrictions on access to it, even when compared with the technical assistance and rural development. Range of access is [-10,6].
Asscomprod	The (communitarian or producers) associations organize the community politically and administratively. There are numerous associations in SRTS, and in the same village one can find more than one association.	Rural space	The rural space is the greatest asset of this socioterritorial system. This is the source of production, environmental problems, conflicts and stage of the main social processes. The farmer, represented here by the community associations and producers, is its guardian. Access this feature means having access to family farmers and their activities. The access may not be complete and is rarely inaccessible, [-9,9].
Banco	The Banco do Nordeste, the World Bank and the Banco do Brasil finances projects for local sustainable development of low cost, especially.	Financial resources	The funding comes from various sources, but stand out from the Banco do Nordeste, the Banco do Brasil and the World Bank. It is a restricted resource which depends on good projects and good partnership among various social actors. Its proper use requires a cooperative social game. The range of access is [-6,6].
Condem_ Cmds	The Economic Council for Municipal Development / The Municipal Council for Sustainable Development.	Plan for municipal development	The plan for municipal development by CONDEM (Economic Council for Municipal Development) or the CMDS (The Municipal Council for Sustainable Development) is more political than concrete. Linked to policies and municipal resources it shall depend on the local political feature and local economic dynamism. It can assume extreme situations, [-10,10].
Prefeitura	Municipal administration.	Public policies for municipal's sustainable development	As its name states, public policies for sustainable development shall be guided more by the immediate interests from politicians and by historical economic activities. Often the policies of the departments of agriculture, economics and finance, and the environment are not coordinated. This resource can assume extreme situations, [-10,10].
Sindicato	Rural workers' Union.	Sociopolitical mobilization	Meant sociopolitical mobilization as the ability of the Union of rural workers to mobilize people and material resources for the defense of Union ideology. Here is an opposition to the ideologies and actions of social actors linked strongly with the municipalities. Range of access is equal to [-9,9].
Embrapa	Brazilian Agricultural Research Corporation.	Technological knowledge	Technologies, products or process developed by the Embrapa that are at the disposal of the society. The access to it is extremely limited due to various social and not social aspects of our society, [-5,5].

TABLE II. STAKES DISTRIBUTION (**S**). SOURCE: ELABORATED BY THE AUTHOR.

Resource	**Social Actors**							
	Pronese	***Emdagro***	***Asscomprod***	***Banco***	***Condem_Cmds***	***Prefeitura***	***Sindicato***	***Embrapa***
Consulting on SD	1	1	1.5	**3**	1	0.5	0	0
Technical assistance and rural extension	1.5	1.5	1.5	2.5	1	0	1.5	2
Technology diffusion	0	0.5	0	0	0.5	0	0	**4**
Rural space	**3.5**	**2**	1	1	2	2	**3**	3
Financial resources	2	1.5	**3**	1	0.5	2	1.5	0
Plan for municipal development	0.5	1	0.5	0.5	1	**2**	1.5	0
Public policies for municipal's sustainable development	0.5	1	1	0.5	**2.5**	1	1	0
Sociopolitical mobilization	0.5	0.5	0.5	1	1	2	1	0
Technological knowledge	0.5	1	1	0.5	0.5	0.5	0.5	1

TABLE III. EFFECT FUNCTIONS (**E**). SOURCE: ELABORATED BY THE AUTHOR.

Resource	**Social Actors**							
	Pronese	***Emdagro***	***Asscomprod***	***Banco***	***Condem_Cmds***	***Prefeitura***	***Sindicato***	***Embrapa***
Consulting on SD								
Technical assistance and rural extension								

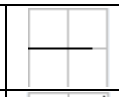
Technology diffusion								
Rural space								
Financial resources								
Plan for municipal development								
Public policies for municipal's sustainable development								
Sociopolitical mobilization								
Technological knowledge								

TABLE IV. AVERAGES AND DEVIATIONS OF SOCIAL ACTOR'S ACTION CAPACITY (C_n) AND RESOURCE'S STATE (s_{mn}) FOR ALL CONVERGED COOPERATIVE SIMULATIONS. SOURCE: ELABORATED BY THE AUTHOR.

Social actor	***Action's Capacity*** (C_n)		***Resource***	***States*** (s_{mn})	
	Average	***Standard deviation***		***Average***	***Standard deviation***
Pronese	49.30	6.00	Consulting on SD	9.72	0.44
Emdagro	20.62	6.19	Technical assistance and rural extension	3.37	1.58
Asscomprod	35.86	5.74	Technology diffusion	5.89	0.19
Banco	55.09	3.40	Rural space	7.13	1.62
Condem_Cmds	19.52	6.45	Financial resources	4.93	1.31
Prefeitura	32.12	5.00	Plan for municipal development	1.28	3.71
Sindicato	16.70	7.22	Public policies for municipal's sustainable development	3.16	3.59
Embrapa	41.23	3.08	Sociopolitical mobilization	-8.87	0.21
			Technological knowledge	3.35	2.13

TABLE V. EFFECT, POWER AND ACTION CAPACITY VALUES FOR CONVERGED SIMULATIONS. SOURCE: ELABORATED BY THE AUTHOR.

Social actor	**Social Actors**								***Action Capacity*** (C_n)
	Pronese	***Emdagro***	***Asscomprod***	***Banco***	***Condem_Cmds***	***Prefeitura***	***Sindicato***	***Embrapa***	
Pronese	9.7	5.9	24.9	7.2	-0.7	-1.6	4.5	0.5	**50.3**
Emdagro	-9.3	13.6	14.2	2.4	-1.3	-3.2	4.5	3.3	**24.2**
Asscomprod	14.6	5.1	-0.6	14.7	1.5	2.6	4.6	-3.3	**39.2**
Banco	29.1	9.7	4.0	1.6	1.5	1.3	8.9	2.7	**58.8**
Condem_Cmds	-9.7	2.3	14.2	0.8	1.3	6.5	8.9	0.5	**24.8**
Prefeitura	-4.9	0	5.9	9.8	6.2	3.2	17.8	-1.0	**37.0**
Sindicato	0	0.4	21.3	-7.3	-2	-3.2	9	-1	**17.2**
Embrapa	0	30.4	8.8	0	0	0	0	3.3	**42.5**
Power (P_n)	**29.5**	**67.4**	**92.6**	**29.1**	**6.7**	**5.7**	**58**	**5**	
Cooperative Power (P_n^c)	**53.4**	**67.4**	**93.2**	**36.4**	**10.6**	**13.7**	**58**	**10.3**	