DEVELOPMENT OF GLOBAL AND LOCAL CONCEPTUAL MODELS IN SUPPORT OF THE "RATIONAL" USE OF WATER IN IRRIGATED AGRICULTURE

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ABSTRACT

Two conceptual models, global and local, are proposed in support of the assessment of the "Rational Use of Water in Irrigated Agriculture" (RUWIA). This study was developed from the experience of local co-management that has been built in the pilot-catchment of Sossego creek (Espírito Santo State - Brazil). The global model, amongst other advancements, allows broadening the discussion about the theme RUWIA, besides helps in the systematisation of the different intervenient aspects in the process (social, political, economic, environmental, technical). The local model, represented here by the case of the Sossego catchment, allows the discussion and understanding of how adaptivity, participation, integration and decentralisation, amongst other precepts of the new water resources management paradigm, are considered in the everyday practice of the related stakeholders and how the interaction of their different types of knowledge can contribute in higher resilience and lesser uncertainties inherent to water resources management.

Key-words: water resources management, adaptivity, co-management

INTRODUCTION

Two conceptual models, global and local, are proposed in support of the assessment of the "Rational Use of Water in Irrigated Agriculture" (RUWIA). This effort is justified given the significance of irrigated agriculture worldwide, both for its socio-economic benefits and negative socio-environmental impacts, and this reality demands the seek for a better use of agricultural water, mainly as the growth of the population and of the consumption standards are observed.

An important limitation in the seek of a better use of water resources in agriculture is the understanding of what "rational use/rationalisation" would be and how this concept has been applied in practice. The authors of this paper suggest that such "rationality" has predominantly reflected a vision based on the use of high-tech irrigation systems (e.g. drip irrigation and centre pivot) and huge investments in irrigation engineering (e.g. big dams and canals) as the way to solve problems related to the use of water in irrigation. This perspective is directly linked to simplistic processes of efficiency increase and production and profit maximisation which frequently end up negatively affecting social and environmental variables (cf. Lopes e Teixeira, 2008, 2009 e 2010).

Aiming at promoting wider debate in RUWIA thematic, by embracing social, cultural, political and institutional aspects beyond usual technical, economic and environmental aspects, the construction of the proposed models has the following objectives: to systematise different aspects related to RUWIA thematic, usually dispersed; to bring about/to highlight important elements in RUWIA, usually neglected in the dominant irrigation science; to highlight the importance of considering the feedback in between global and local models/levels; to analyse in an integrated manner aspects related to water resources, agricultural and irrigation managements, for the socio-economic importance of agriculture which is the greater water user sector worldwide.

The key-discussion to move forward towards adaptivity, participation, integration and decentralization, amongst other precepts of the water management paradigm, is to reflect upon how have been the practices in global and local levels and the relationships in between these two levels.

The analysis presented here, how such aspects are put into the usual practice of all involved stakeholders and how the interaction of different knowledges can contribute in higher resilience and lesser uncertainties inherent to water resources management, has been possible due to the experience of local co-management developed in the pilot catchment of Sossego creek (located in the city of Itarana, Espirito Santo State), a sub-basin of Santa Joana river which is a direct affluent of Doce river (Figures 1 and 2) – a river of great importance to Brazil.

CONSTRUCTION OF GLOBAL AND LOCAL MODELS FROM THE EXPERIENCE OF PILOT CATCHMENT OF SOSSEGO CREEK (ITARANA, ESPIRITO SANTO, BRAZIL)

The process of construction of conceptual models in support of RUWIA in the pilot catchment of Sossego creek has been run by the development of different activities whereby the visions of local producers, institutions and other actors were integrated. Such activities in Sossego creek catchment constitute as one set of actions developed in what is commonly referred to as the Sossego Project. The past and ongoing actions and research undertaken at the Sossego micro-catchment have turned it into a 'living laboratory' for the water resources, agricultural and irrigation sectors in Brazil. It is possible to draw a line between 'experimental catchment' and 'living laboratory' in the sense that, in the latter, techniques/technologies are not only applied, evaluated and improved, but it is also possible to undertake in-situ observation and research integrated with social, environmental, economic, technical, political and institutional aspects. The approach adopted in the Sossego Project aims at proposing appropriate strategies to local realities in order to avoid the imposition of "ready packages" or "black boxes", i.e. the application of a science that only "observes / formulates / dictates", but a science that provides tools and alternatives to the society for collective definition of how to appropriately deal with their specific problems and opportunities.

The Sossego creek catchment has an approximate area of 65 km^2 whereby there are approximately 200 properties and a rural population of 800 inhabitants. Eighty-five percent (85%) of the properties have areas ranging from 10 to 50 hectares, with predominance of family-based smallholders. With regard to agricultural production, coffee (*Coffea canefhora* L.), banana (*Musa* spp.) and yam (*Colocasia esculenta*) are actually the most representative crops in terms of cultivated area and profit. Besides these, livestock, horticulture and fruit growing are also significant. The basin is considered very productive and what is produced supplies mainly the Great Vitoria (region which includes the city of Vitória, capital of Espírito Santo State), but part is also sold in the neighbouring municipalities and exported to other countries.

The history of interventions (drainage and dredging of streams and intensification of irrigation) in the watershed over the decades, and the high spatial and temporal variability of rainfall (dry and rainy periods), can explain the problems of water scarcity and of conflicts over the use of water that have repeatedly occurred and that seem to be intensified in recent years. The situation gets worse, since is not observed a robust process of social and political organization to try to reverse the problem locally as well as the idea of integrated/participatory water/natural resources in the basin is still new (and in practice perhaps in the whole country). It is also observed an individualist vision of farmers who, through ignorance or lack of will, do not understand the consequences of their interventions in the whole basin.

In this context, the experience of construction of a local model in the Sossego creek catchment is an effort in order to continue reducing the deficit of experiments that assess the relationship between different kinds of knowledge and the institutional and organizational aspects of different models of adaptive and integrated governance of water.

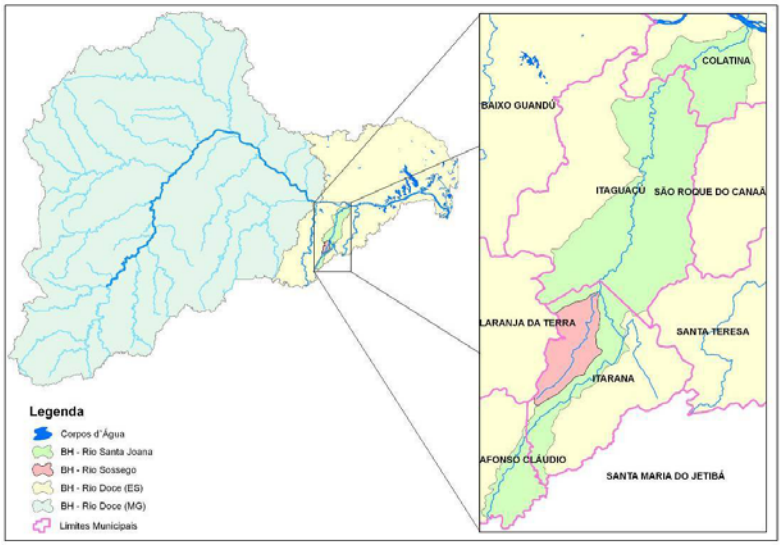

Figure 1 – Insertion of Sossego creek catchment (in pink) in Doce river basin. In yellow and blue, respectively, Espírito Santo and Minas Gerais State portions of Doce river basin. In green, Santa Joana river basin.

Figure 2 – Sossego creek catchment (in pink) located in the city of Itarana, Espírito Santo State, Southeast region of Brazil. In yellow, the Espírito Santo State portion of Doce river basin (see more details in Figure 1, above).

METHODOLOGY

Global and Local Models have been constructed through a series of activities held under Sossego Project, during the development of PhD thesis (Lopes, 2011). The adopted methodology is presented as follows:

Global Model

The methodology for this stage has basically consisted of the development of a theoretical framework and the systematisation of knowledge related to theme RUWIA. It was analysed how this theme has been approached in the literature and in practice in order to establish possible trends or existent currents still not totally clear in terms of conceptualisation and application.

The first step was the etymological and historical analysis of the concepts "reason", "rationalisation" and "rationality" in order to justify discussions about how such terms have been applied and understood and how this reflects into RUWIA. The second step, which consisted of specific survey of documents that mention RUWIA. Thus, it was possible to present the state of art RUWIA what has later allowed the construction itself of the conceptual models [for more details regarding these results see Lopes (2011)].

The adopted approach for the discussions presentation was the Critical Theory, which fits in the development of this activity as many interpretations on the theme RUWIA are evaluated and discussed. As Guba and Lincoln (1994, p.110) put it "a realism is assumed to be apprehendable that was once plastic, but that was, over time, shaped by a congeries of social, political, cultural, economic, ethnic, and gender factors, and then crystallised (reified) into a series of structures that are now (inappropriately) taken as 'real', that is, natural and immutable…". It is important to highlight that beyond theoretical discussion, direct participation and observation in events, meetings, interviews and workshops were also necessary in the development of activities.

From the information obtained during the aforementioned activities, two conceptual models of RUWIA were built: Rational-Hegemonic Model and Rational-Ample Model (Tables 1 and 2).

Such models were systematised in order to: allow easier visualisation of two complementary but antagonist trends observed in RUWIA thematic; systematise different aspects related to RUWIA thematic, usually dispersed; to bring about/to highlight important elements in RUWIA, usually neglected in the dominant irrigation science; to analyse in an integrated manner aspects related to water resources, agricultural and irrigation managements.

The models were organised in "Themes" and "Descriptors". "Themes" would be the main groups which contain the aspects taken into consideration in problem analysis and "Descriptors" would be significant characteristics of a theme according to the main attributes of a certain system (Marques et al. 2003).

After the descriptor level, the "Indicator" level would naturally occur. "Indicators" express the effect of the system action upon a descriptor (*Ibid*, 2003). Thus the indicator level was only explored in the local model once it is possible to consider the local specificities in the analysis.

Local Model

The local model was built through a series of activities taken the global model (Rational-Hegemonic Model and Rational-Ample Model) as the conceptual reference.

Action-Research, as a research method based on the constructivist paradigm, was adopted in this stage. This is justified given the twofold role of the researcher as observer and facilitator. It was necessary to the development of this research which deals with the analysis of a complex social process whereby participants' subjectivity and constructions of reality were taken into account. In this sense, a mix of quantitative and qualitative methods was utilised to reach the intended goals.

The first step in the process of construction of the local model was the initial structuring of the problem with farmers [represented by the 39 members that constitute the Sossego Project's Community Coordinator Group

(CCG – *Grupo Coordenador da Comunidade*) – 3-4 representatives, with at least one woman, democratically elected by each one of the 12 communities which compose Sossego creek catchment]. A survey regarding Sossego creek's problems and its potential solutions was made, embracing not just water related problems but also health, education, security etc. Thus, meetings were held in order to define the best way to run workshops for the validation and adjustment of problems and propositions listed by the CCG, in this case restricting the assessment to the problems related to water use.

The following step was the workshops with all 12 communities utilising River Basin Game (Lopes, 2011; Magombeyi et al., 2008; Lankford et al., 2004) whereby problems and action alternatives to the resolution of problems of local management were systematised and criteria and subcriteria were constructed to be lately utilised in Multicriteria Analysis. Such criteria and subcriteria (Tables 3-7) are: 1) Irrigation Management (subcriteria: Enhancement of irrigation systems; Enhancement of irrigation management; Crop planning); 2) Non-structural actions/transversal themes (subcriteria: Better institutional performance; Better farmer performance; Capacity building and communication); 3) Practices of water storage/distribution (subcriteria: Construction/adjustment of dams; Construction/adjustment of reservoirs; Water distribution mechanisms); 4) Practices of water and soil conservation (subcriteria: Construction and maintenance of "infiltration boxes"; Adoption of soil and water conservation practices); 5) Reforestation/Recovering of springs and degraded areas (subcriteria: Reforestation and recovering of springs and degraded areas; Restoration of streams and reversion of dredging/drainage).

Besides the realisation of surveys with local stakeholders (farmers and institutions), technical-scientific studies have been carried in the catchment regarding social and environmental aspects as well as, concomitantly to the aforementioned workshops, technical visits to the catchment were made with specialists (Agronomists, Geographers, Biologists, and other specialists in water and soil conservation, irrigation, hydrology, forestry, etc.) in order to point out the main problems and possible alternatives in the vision of these.

The final stage was the application of Multicriteria Analysis. The first activity consisted of the realisation of training workshops for the use of a multicriteria method (Weighted Average Method) whereby institutions and farmers worked separately. In the second activity such groups worked together with the formation of steering committees for each one of the 5 criteria.

From the information obtained in the workshops and other studies it was possible to define indicators of local management. Theses indicators are related to descriptors (stemmed from the Rational-Ample Model) that were selected for each criterion (and subcriteria) which compose the local model (Tables 3-7). For more details regarding the methodology adopted to the construction of the local model and obtained results see Lopes (2011).

RESULTS AND DISCUSSION

The Tables 1 and 2 present two global-conceptual models: Rational-Hegemonic Model (RHM) and Rational-Ample Model (RAM).

The RHM (Table 1) represents how predominant literature and policies in the theme RUWIA understand the search for a "rational use" of water in agriculture.

One can observe that RHM presents only "Environmental" and "Technical-Economic" themes.

The first theme, "Environmental", describes the main environmental requirements related to water use in irrigation that must be considered when an irrigation project is implemented. In other words, the ecological flow must be observed and aquifers preserved (e.g. preservation of ecological functions of natural ecosystems and access of water for other users), ecosystems must be preserved [e.g. preservation of areas protected by national law – as Permanent Preservation Areas ("*Áreas de Preservação Permanente*") and Conservation Unities ("*Unidades de Conservação*") in Brazil], and the observation of soil and water quality requirements.

The second theme, "Technical-Economic", points out the main technical requirements of irrigation that must be considered from the economic analysis of the irrigation system and the crop that will be selected. The

equipment to be adopted is that which provides the best profitability to the producer, given the prerogatives of environmental legislation.

THEME 1 – Environmental	THEME 2 – Techinical-Economic
Descriptor 1.1	Descriptor 2.1
Ecological flow	**Irrigation management**
Descriptor 1.2	Descriptor 2.2
Aquifers conservation	**Irrigation project**
Descriptor 1.3	Descriptor 2.3
Ecosystems conservation	**Equipment maintenance**
Descriptor 1.4	Descriptor 2.4
Water quality requirements	**Water storage infra-structure**
Descriptor 1.5	Descriptor 2.5
Soil quality requirements	**Water Use Efficiency and Water Productivity**

Table 1 – Rational-Hegemonic Model (RHM).

Thus, irrigation project, irrigation management, equipment maintenance and water storage infra-structure are the main technical requirements, represented in the RHM as “Descriptors”. Furthermore, Water Use Efficiency and Water Productivity are indicators (Descriptor 2.5) that have more recently been adopted by the formal irrigation science.

In general, the prevailing view has focus on the expansion of water storage infrastructure and on the improvement of water use efficiency, primarily through enhancements in systems and irrigation management at the farm level, as highlights Wichelns (2003). Such reality can be illustrated by examples mainly from developing countries as Brazil and South Africa, where current policies have encouraged the expanded use of irrigation (Christofidis, 2008; Lankford, 2009).

However, despite the greater control of water abstraction (e.g. through “water permits” – an instrument of the Brazilian Water Resources Policy) in order to keep water sources at adequate levels, in this model it is not effectively observed an integrated vision whereby other factors and impacts in the collectivity should be considered when adopting a particular practice.

The observance of inadequate results of water use in irrigation worldwide, even in high efficiency systems (Oliveira et al., 2009; Teixeira et al., 2007; Lopes, 2006; GEARH/LABGEST, 2006; Elder et al., 2005; Luquet et al., 2005; Bontemps e Couture, 2002; Pereira et al., 2002; Skaggs, 2001; Barth, 1999; Bonomo, 1999; Capra e Scicolone, 1998) is a clear picture that the current model of RUWIA needs to improve. Technical advances of irrigation are important but other aspects related to specific local conditions, such as socio-economic constraints, patterns of behavior and production expectations have not been adequately incorporated in the debate. This situation may be occurring as the understanding of rationalisation is still very much connected to the idea of technical improvements of equipment to increase productivity, which follows a simplified logic that does not consider different realities and other significant aspects.

In this sense, the RAM (Table 2), as its very name means, is an attempt to expand the analysis of RUWIA by incorporating and highlighting other aspects and discuss their interrelations. The model was organized by themes "Environment", "Technical", "Political-Economic" and "Socio-Cultural." One might question that these last two themes could already been permeated in the RHM, but the intent of the construction of RAM is precisely to strengthen / clarify that other aspects should also be evident in the analysis.

The economic aspect, previously embedded in the technical aspects of the RHM, becomes incorporated into the political factor of RAM. This was done to highlight the analysis of the economic factor in a broader plan, in the setting more inclusive and democratic policies and government programs. Thus, on one hand the "Political-Economic" theme emphasizes the macro policies scale, and on the other hand the "Socio-Cultural" theme tries to bring out more clearly the local scale and its specificities. Consequently, one tries to better evaluate the interrelationships between the macro and micro scales.

THEME 1 – Environmental	THEME 2 – Technical
Descriptor 1.1 **Ecological flow** Descriptor 1.2 **Aquifers conservation** Descriptor 1.3 **Ecosystems conservation** Descriptor 1.4 **Water quality requirements** Descriptor 1.5 **Soil quality requirements**	Descriptor 2.1 **Irrigation management** Descriptor 2.2 **Irrigation project** Descriptor 2.3 **Equipment maintenance** Descriptor 2.4 **Water storage infra-structure** Descriptor 2.5 **Water Use Efficiency and Water Productivity**
THEME 3 – Political-Economic	**THEME 4 – Socio-Cultural**
Descriptor 3.1 **Market and price policies** Descriptor 3.2 **Subsidies for inputs purchase** Descriptor 3.3 **Subsidies for enhancement/purchase of irrigation systems** Descriptor 3.4 **Technical assistance** Descriptor 3.5 **Destination of the irrigated crops** Descriptor 3.6 **Implementation of agricultural/environmental/water resources policies** Descriptor 3.7 **Dynamics of water storage/distribution** Descriptor 3.8 **Inter-institutional and institutions-society relationships**	Descriptor 4.1 **Level of knowledge about agricultural/environmental/water resources policies** Descriptor 4.2 **Community organization/participation** Descriptor 4.3 **Model(s) of agricultural production** Descriptor 4.4 **Local labour** Descriptor 4.5 **Access to natural/water resources**

Table 2 – Rational-Ample Model (RAM).

Thus, the RAM can serve as a basis for some questionings that have been observed from the descriptors that compose it. In this sense, some questions are posed to illustrate how these descriptors can help in the debate of each subject and later in the definition of local indicators. It is noteworthy that some questions are put to more than one descriptor, given the higher affinity between some of them.

- THEME 1 – Environmental:

Descriptors "Ecological flow" and "Aquifers conservation": How ecological (or minimum) flows have been defined (e.g. $Q_{7,10}$ or Q_{90})? Are current methodologies utilised by the environmental institutions appropriate? What are the limitations in studies on the interference of use of water in aquifers?

Descriptor "Ecosystems conservation": What are the relationships between the need to conserve ecosystems, promote water conservation, soil and biodiversity and to ensure agricultural production, and specifically, the development of rural areas? To what extent do current laws apply to all conditions and encourage appropriate and sustainable agricultural production?

- THEME 2 – Technical:

Descriptors "Irrigation management", "Irrigation project" and "Equipment maintenance": In terms of available volume and farmers financial situation, can one justify a complete change of irrigation systems? Could one improve the current system instead? What are the causes and constraints that generate poor results observed in design, management and maintenance? What alternatives are feasible and appropriate for each specific case in short, medium and long terms?

Descriptors "Water storage infra-structure" and "Water Use Efficiency and Water Productivity": To what extent Water Use Efficiency and Water Productivity assessments can be applied in cases where there is an urgent need to discuss more basic questions, such as mechanisms for reservation and more equitable distribution of water? Even in more advanced situations (large properties with high technological level), such analysis would

not be far from the daily practice of producers / users of water once it relies on highly specialized technical-scientific knowledge?

- THEME 3 – Political-Economic

Descriptors “Market and price policies” and “Destination of the irrigated crops”: What is the value of water when compared to other inputs (electricity, fertilizers, labour, etc.) and how does it interfere in its use? Water is used for crop irrigation with what purposes: subsistence, exportation, local / regional market? Are there subsidies for the inputs purchase, acquisition / improvement of irrigation systems and use of electricity for irrigation? What are the crops grown under irrigation (subsistence, high market value) and how does it interfere in the adopted systems? Is the pattern of local agricultural production diverse, or dependent on irrigation? Are less water demanding crops grown in cases of prolonged periods of drought? Is there adequate market infrastructure to support such changes in water availability (and therefore variations of what is produced)?

Descriptors “Technical assistance” and “Inter-institutional and institutions-society relationships”: Is there a formal apparatus of public and private technical assistance and what is the quality of service? Are there "certified" / "licensed" companies selling irrigation equipment with qualified professionals (technical responsibility) for design, installation and maintenance of equipment? How is the performance of the environmental and technical assistance institutions (guidance and flexibility or punishment and enforcement)?

Descriptor “Implementation of agricultural/environmental/water resources policies”: What is the level of implementation of agricultural, environmental and water resources policies through the responsible agencies?

Descriptor “Dynamics of water storage/distribution ”: What is the infrastructure model of water storage and distribution (private or public dams, watershed without formal infrastructure)? Is the existing infrastructure being well managed and promoting equitable distribution of water?

- THEME 4 – Socio-Cultural:

Descriptor “Level of knowledge about agricultural/environmental/water resources policies”: Are principles, fundamentals and objectives of policies known and well understood? How local authorities have implemented their policies?

Descriptor “Community organization/participation”: What is the level of community organization, mobilization and participation (associations, cooperatives, committees, etc.)? How does historical and cultural context influence on participation and social organization? How do policies and interventions of government (national, state and local levels) influence the local participation over the years?

Descriptor “Model(s) of agricultural production”: Which is(are) the observed model(s) of agricultural production? Smallholder farming, agribusiness, conventional or organic agriculture? Are there incentives for alternative production models or just for the dominant models? How different models of production affect water use in agriculture?

Descriptor “Local labour”: What is the availability and type of labour, training (agronomic, level of education, capacity of technology absorption) of the producers? How is the dynamics of labour as a result of adoption of irrigation systems? What is interest of youngsters to work with rural activities?

Descriptor “Access to natural/water resources”: How are gender issues, social class and age inserted in the debate of access to natural / water resources?

It is noteworthy that the proposed systematization for the models is not closed and can be modified when necessary. The conceptual models are presented as a first effort to systematize the complexity of the theme RUWIA and broaden its scope and understanding.

In conclusion, evidence suggests that the key debate to progress on the participation, integration and decentralization, the main precepts of the new paradigm of water management, is to consider how are the practices in the global (dominant discourses and policies) and local (practices and particularities of each place) levels and the inter-relationship between them.

It is necessary to move forward regarding analysis concerning how the various aspects presented in RAM are put in daily practice of the involved actors and how better interaction between these actors could contribute in a greater local resilience and in the sharing of risks and uncertainties inherent to water resources management (Lankford e Hepworth, 2010; Lannerstad e Molden, 2009; Folke et al., 2005).

Tables 3-7 present the systematization of information obtained during the activities carried in the basin (participatory workshops and scientific and technical surveys) which culminated in the structuring of the local model. RAM served as a reference for such organization. Accordingly, for each criterion (and its sub-criteria) it was possible to use descriptors of the RAM, and from there, define indicators.

In a first moment, we sought to understand the problem and gather possible solutions to its resolution with no value judgments as to whether the proposals would be appropriate or whether something have not been considered in the analysis of the problem. This is justified because a constructive process in the search for adaptivity goes through a series of events that are gradually discussed and detailed with the participation of all actors involved in the problem.

The proposals analysis brought by experts, institutions and farmers has continuously been carried in the catchment, trying to consider what can be done in the short, medium and long terms and what are the commitments of all stakeholders for the implementation of the proposals according to the local conditions (financial, social, political, natural, etc.).

It is understood that the organization of the problem through the definition of priority points, the establishment of actions and commitments of stakeholders highlight the need to integrate different knowledge / visions in order to solve problems. For example, improved management of local irrigation depends, among other actions, both for greater empowerment of producers and the provision of technical information required to define when and how much to irrigate. Thus, producers are aware that they need to be trained and the institutions aware of their role in promoting training courses and more technical assistance towards the proper use of water for irrigation.

The structure presented in Tables 3-7 consists of a robust and reliable systematization of the local observed problem and it is of great value to the ongoing debate within the Sossego creek catchment. However, in order to enable effective insertion of the precepts of adaptivity, it can be adjusted later as an attempt to reduce uncertainty and increase local resilience, objectives pursued in water resources management.

Some important points observed through the data collected in the region and in the organized participatory workshops are discussed as follows.

In the "Irrigation Management" criterion (Table 3), a critical point is that the design of irrigation projects is carried out mostly by farmers or sellers of irrigation equipment which usually have no technical training to do so. In addition, there are generally no programs in agricultural extension agencies in Brazil to promote the improvement of irrigation management through capacity building of producers and technicians. The situation is still problematic by the difficulty to make a proper irrigation management due to the requirement of technical data (climate, soil, water, irrigation system, culture, etc.). In the case of Sossego creek catchment (and other regions of Brazil and the world), even with the adoption of irrigation localised systems (drip, microsprinkler, etc.) conflicts over water use persist and seem to be intensifying.

Regarding the "Practices of water and soil conservation" criterion (Table 6), the construction of “infiltration boxes” in on-farm roads can be accomplished with the support of institutions (which may provide machinery) while the adoption of other conservation practices is only possible by farmer's own will, within the property. In this discussion are included the concern of producers to get no guarantees of benefit as a result of the change, financial constraints that impede the adoption of other practices and simple unwillingness to change the land management practices currently employed.

IRRIGATION MANAGEMENT - Enhancement of irrigation systems - Enhancement of irrigation management - Crop planning RAM themes: THEME 2 – Technical THEME 3 – Political-Economic THEME 4 – Socio-Cultural	Descriptor 2.1-**Irrigation management** **Local indicator:** There is no irrigation management based on technical criteria **Local indicator:** There is evidence that some practices appropriate to local crops (coffee and banana) are already adopted though they are not entirely adequate Descriptor 2.2-**Irrigation project** **Local indicator:** The majority of projects is usually designed by producers and sellers of equipment without technical training **Local indicator:** There is a growing trend in the adoption of localised irrigation systems (microsprinkler, microjet, drip irrigation) Descriptor 2.3-**Equipment maintenance** **Local indicator:** The maintenance of irrigation systems has improved under Sossego Project activities but is still incipient Descriptor 3.1-**Market and price policies** **Local indicator:** Localised irrigation systems have been adopted predominantly for crops of higher value market (coffee and fruits) and sprinkler systems for horticulture Descriptor 3.2-**Subsidies for inputs purchase** **Local indicator:** There is an increasing adoption of alternative tariffs (cheaper at some hours of the day) of electric energy Descriptor 3.3-**Subsidies for enhancement/purchase of irrigation systems** **Local indicator:** There are financing lines for the purchase of irrigation systems Descriptor 3.4-**Technical assistance** **Local indicator:** There is not enough technical assistance for irrigation issues for all catchment Descriptor 3.8-**Inter-institutional and institutions-society relationships** **Local indicator:** Activities related to irrigation are basically the complaints of some farmers to the environmental agencies regarding water retention by reservoirs and dams in dry periods **Local indicator:** The activities under the Project Sossego have tried to improve these relationships and define joint strategies for agricultural water management Descriptor 4.3-**Model(s) of agricultural production** **Local indicator:** The predominant production model is based on smallholder farming ("*pequenos agricultores de base familiar*"), utilising methods of conventional agriculture whose production is largely irrigated Descriptor 4.4-**Local labour** **Local indicator:** The local labour for irrigation has still low qualification

Table 3 – Local indicators to the criterion "Irrigation management".

NON-STRUCTURAL ACTIONS (TRANSVERSAL THEMES) - Better institutional performance - Better farmer performance - Capacity building and communication RAM themes: THEME 3 – Political-Economic THEME 4 – Socio-Cultural	Descriptor 3.4-**Technical assistance** **Local indicator:** Regarding irrigation issues, there is no proximity between institutions and producers **Local indicator:** Regarding conservation practices and reforestation and recuperation of degraded areas, there are incentives from institutions but still poor adherence by farmers Descriptor 3.6-**Implementation of agricultural/environmental/water resources policies** **Local indicator:** Policies are generally implemented through command and control instruments and in an imposing manner by institutions Descriptor 3.8-**Inter-institutional and institutions-society relationships** **Local indicator:** The relationships are still fragile but the activities carried out under the Sossego Project have provided higher proximity between actors Descriptor 4.1-**Level of knowledge about agricultural/environmental/water resources** **Local indicator:** Knowledge is usually constructed from the application of command and control instruments and when there are subsidies supporting production Descriptor 4.2-**Community organization/participation** **Local indicator:** The social organization is still incipient but has been strengthened by Project Sossego activities Descriptor 4.4-**Local labour** **Local indicator:** The local labour for irrigation has still low qualification

Table 4 – Local indicators to the criterion "Non-structural actions (Transversal themes)".

PRACTICES OF WATER STORAGE/DISTRIBUTION - Construction/adjustment of dams - Construction/adjustment of reservoirs - Water distribution mechanisms RAM themes: THEME 1 – Environmental THEME 3 – Political-Economic THEME 4 – Socio-Cultural	Descriptor 1.1-**Ecological flow** **Local indicator:** There is no precise data Descriptor 1.2-**Aquifers conservation** **Local indicator:** There is no available data Descriptor 1.3-**Ecosystems conservation** **Local indicator:** Studies point to the qualitative and quantitative degradation of water Descriptor 3.4-**Technical assistance** **Local indicator:** There is an office of the agency responsible for licensing of small dams/reservoirs near the catchment Descriptor 3.7-**Dynamics of water storage/distribution** **Local indicator:** Water storage made predominantly by small reservoirs **Local indicator:** There is no information about the current water storage capacity in the catchment Descriptor 3.8-**Inter-institutional and institutions-society relationships** **Local indicator:** The predominant kind of relationship between producers and institutions usually occurs when there are licensing of dams and complaints Descriptor 4.2-**Community organization/participation** **Local indicator:** There is no formal organization of producers regarding water storage / distribution issues. Complaints are made directly to the regulatory agencies **Local indicator:** Some producers share the stored water, especially during dry seasons Descriptor 4.5-**Access to natural/water resources** **Local indicator:** The management of natural / water resources is predominantly carried by men **Local indicator:** Complaints are made directly to the regulatory agencies as a result of conflict over access to water, especially during dry periods

Table 5 – Local indicators to the criterion “Practices of water storage/distribution”.

PRACTICES OF WATER AND SOIL CONSERVATION - Construction and maintenance of “infiltration boxes” - Adoption of soil and water conservation practices RAM themes: THEME 1 – Environmental THEME 3 – Political-Economic THEME 4 – Socio-Cultural	Descriptor 1.1-**Ecological flow** **Local indicator:** There is no precise data Descriptor 1.2-**Aquifers conservation** **Local indicator:** There is no available data Descriptor 1.4-**Water quality requirements** **Local indicator:** Studies point out to the qualitative and quantitative degradation of water Descriptor 1.5-**Soil quality requirements** **Local indicator:** Studies point out that the adopted land management practices have favoured the installation of erosion Descriptor 3.5-**Destination of the irrigated crops** **Local indicator:** There is the encouragement by local technical assistance towards the adoption of conservation practices, but financial constraints and lack of available machinery, are limiting factors for the effective adoption of some practices Descriptor 3.6-**Implementation of agricultural/environmental/water resources policies** **Local indicator:** There is a State level program for the adequacy of rural properties Descriptor 4.1-**Level of knowledge about agricultural/environmental/water resources policies** **Local indicator:** Given the limitations of local technical assistance and supervisory bodies and the fragility of social organization, policies are implemented in a reactive way, for instance when fines or command and control instruments are applied Descriptor 4.4-**Local labour** **Local indicator:** The low training of producers, financial constraints and lack of interest hinder the adoption of conservation practices

Table 6 – Local indicators to the criterion “Practices of water and soil conservation”.

REFORESTATION/RECOVERING OF SPRINGS AND DEGRADED AREAS - Reforestation and recovering of springs and degraded areas - Restoration of streams and reversion of dredging/drainage RAM themes: THEME 1 – Environmental THEME 3 – Political-Economic THEME 4 – Socio-Cultural	Descriptor 1.1-**Ecological flow** **Local indicator:** There is no precise data Descriptor 1.2-**Aquifers conservation** **Local indicator:** There is no available data Descriptor 1.3-**Ecosystems conservation** **Local indicator:** 30% of the catchment area is covered by native vegetation in different successional stages **Local indicator:** 5 out of the 8 Sossego's sub-basins have 20% of forest coverage **Local indicator:** As a result of dredging and drainage occurred in the basin, the majority of the creeks lost their natural meanders and natural flooded areas. Descriptor 1.4-**Water quality requirements** **Local indicator:** Studies point to the qualitative and quantitative degradation of water Descriptor 1.5-**Soil quality requirements** **Local indicator:** Studies point out that the adopted land management practices have favoured the installation of erosion Descriptor 3.2-**Subsidies for inputs purchase** **Local indicator:** Local institutions have mechanisms for facilitated acquisition of inputs for reforestation and restoration of degraded areas (trees, fertilizer, etc.). Descriptor 3.5-**Destination of the irrigated crops** **Local indicator:** There is encouragement of local technical assistance for reforestation but financial and inputs constraints and resistance from producers are limiting factors for the effective adoption of practices (isolation of springs, recovery of Permanent Preservation Areas) Descriptor 3.6-**Implementation of agricultural/environmental/water resources policies** **Local indicator:** There is a State level mechanism of payment for environmental services but still at an experimental stage in some areas **Local indicator:** There is a State level program for the adequacy of rural properties Descriptor 4.1-**Level of knowledge about agricultural/environmental/water resources policies** **Local indicator:** There is a growing environmental awareness among producers, however this is not always reflected in practical actions, as a result of various factors (lack of guarantees of benefits, financial constraints)

Table 7 – Local indicators to the criterion "Reforestation/recovering of springs and degraded areas".

When we assess the "Reforestation/recovering of springs and degraded areas" criterion (Table 7), there is evidence that the producers are aware that reforestation and recovery of degraded springs and other areas are essential to improve the quality and the amount of water in a given basin (the technicians of the institutions already have this knowledge). This may be the result of state and national level programs that have been developed over time on this issue. Still, in much of the basin it is not observed more significant actions especially to the recovery of degraded areas what may be related to, among other things, the lack of financial incentives / subsidies and financial constraints by the owners as well as difficult to envision the benefits in the short to medium term. There is also the difficulty of promoting (at least in the short and medium term) the restoration of Sossego creek due to interventions carried out over time even though it is an important alternative in terms of water retention in the local water system. This stems from the fact that most of the properties productive areas is located on the streams margins, primarily due to the development of PROVÁRZEAS. In conclusion, when discussing reforestation issues discourse and practice are quite different. The theme has been extensively debated and one can already see people's awareness about the importance of maintaining protected areas. The fact is that when thinking in solving the problem of water into a basin, there seems to be a preference in the adoption of structural measures with immediate returns, such as the installation of dams and the construction of reservoirs.

The local model shows, therefore, the importance of the adoption of adaptive management, in cases such as the Sossego creek catchment, for several reasons. For example, resources are used intensively and natural climate variations are observed, there are limitations in the formal management of water due to limited infrastructure and human resources in the institutions and social organization is still fragile. All these factors require greater flexibility in management so that it can be gradually improved and more appropriate management mechanisms can be fitted to local conditions.

The formation of monitoring committees for each criterion, which took place under the Sossego Project, allows the definition of alternatives, commitments and deadlines for achieving management goals. While structural actions do not occur, as they usually require more financial resources and projects, producers and institutions exercise the practice of co-responsibility and the joint construction of knowledge.

This is perhaps the main contribution of this work, understanding how to adopt the most appropriate strategies for each location. In this context, the development of the local model attempts to provide a favorable environment for the most appropriate technologies to be adopted / adjusted / developed entailing greater local involvement and sense of community for the solution of everyday problems.

The local model also highlights the role of specialists and technicians as facilitators and not as those who define what should be done. This reality is opposed to that found in most cases where the farmer is always convinced that the solutions brought by institutions are always better than those they develop over the years.

Therefore, it is important to develop mechanisms whereby the community can show and discuss what are their critical points, as well as successful experiences developed by themselves or in conjunction with institutions. This provides an environment for exchange of experience between farmers (which enables greater adoption of technology adjusted to local) and a greater sense of community.

CONCLUSIONS

The deepening of the theme “Rationalization of Use of Water in Irrigated Agriculture” (RUWIA) demonstrates the existence of a predominant understanding based essentially on technological aspects in the practice of water resources and irrigation management, usually neglecting other relevant aspects such as access equity (gender, social class, social groups), definition and gradual enhancement of rules/techniques/technologies with social participation, which are requirements in the search for sustainable societies.

The Rational-Ample Model (RAM) consists in a methodological advancement once inserts and highlights relevant aspects related to political-economic and socio-cultural dimensions usually neglected in the RUWIA thematic. Thus, the RAM aims at subsidise the consolidation of management models more suitable with the precepts of sustainability and integrated, decentralised and participatory water resources management that underpin the Brazilian Water Resources Policy.

The local model developed in support of the assessment of the use of water in agriculture, whose construction was based on the constructivist paradigm (involving researchers, technicians and local community) shows itself very much promising as a local management tool once shows in a broad manner, in various dimensions (environmental, technical, political-economic and socio-cultural), diverse aspects related to sustainability. It broadens the chances of effectivity of the proposed actions as they are alternatives more suitable and contextualised to the problem of water management that one wants to solve.

The integrated and broadened analysis allowed by the understanding of the global and local models, which consider both irrigation technical aspects and other local aspects (environmental, socio-cultural, political, etc.), points out that even though more efficient irrigation systems have been adopted (e.g. drip and micro-sprinkler irrigation), conflicts in Sossego creek catchment and in other regions keep up increasing. Such reality corroborates the idea that the dominant "rationality" in agricultural water use has not solved the problem and hence wider analyses are required.

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