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ENVIRONMENTAL ENGINEERING

Reflection on the vision of Integrated Management of vulnerability due to water shortages in rural zone of Colombia

INGENIERIA AMBIENTAL

Reflexión acerca de la visión de la Gestión Integral de vulnerabilidad por desabastecimiento de agua en zona rural de Colombia

Aura P. Andrade-Ayala[§], Carlos E. Osorio-Garcés, Juan P. Martínez-Idrobo

Universidad del Cauca, Popayan, Cauca, Colombia

apandrade@unicauca.edu.co, carlososorio@unicauca.edu.co, jpmartinez@unicauca.edu.co

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Abstract

The present review article refers to the management and baking processes to deal with environmental problems, specifically those that have to do with risk by water supply in rural areas, making an analysis of the integral management of water, the different international and national approaches, to reach the approach in Colombia and how the country welcomes these global guidelines for the proper management of water; It also proposes the analysis of three concepts that make it possible to complement IWRM, as a central approach that promotes multiple convergences from the academic sphere, such as adaptive management, resilience and governance to strengthen the systemic approach required in the management of water under the premise of sustainability. As a consequence of this analysis, the microbasin is considered as a socioecosystem given the intrinsic characteristics to provide water for different uses, being adversely affected by climatic anomalies, which deserves an analysis of the vulnerability of supply microbasins to climate change and climate variability to make a critical approach to the problems in the region in terms of management.

Keywords: *Adaptive capacity, Risk, Supply, Water, Vulnerability*.

Resumen

El presente artículo de revisión refiere a los procesos de gestión y panificación para hacer frente a problemáticas ambientales, específicamente a las que tienen que ver con la vulnerabilidad por abastecimiento de agua en las zonas rurales, haciendo un análisis a la gestión integral del agua, los diferentes abordajes internacionales y nacionales, para llegar al contexto nacional de Colombia y como acoge el país estos lineamientos mundiales en procura de la gestión apropiada del agua , se propone también el análisis de tres conceptos que permiten complementar la Gestión Integral del Recurso Hídrico (GIRH), como planteamiento central que promueve convergencias múltiples desde el ámbito académico como lo son: La gestión adaptativa, la resiliencia y la gobernanza para fortalecer el abordaje sistémico requerido en el manejo del agua bajo la premisa de sostenibilidad. Como consecuencia de este analisis se plantea la microcuenca como un socioecosistema dadas las características intrínsecas para proveer agua para diferentes usos, siendo estas afectadas adversamente por las anomalías climáticas lo cual merece un analisis de la vulnerabilidad de microcuencas abastecedoras ante el cambio climático y la variabilidad climática para hacer un planteamiento critico de la problemática en la región en términos de gestión.

Palabras Clave: *Abastecimiento, Agua, Capacidad adaptativa, Riesgo, Vulnerabilidad.*

1. Introduction

Reflection about the vision of integral management of vulnerability due to water shortages in rural zone

This article reviews the conceptual and historical background of integrated water management in international and national contexts. Its importance lies in the fact that the analysis is carried out from the linkage of three complementary concepts of Integrated Water Resource Management, which are: adaptive management, resilience and governance. These concepts allow a fundamental systemic vision for water management in the framework of sustainability; as a consequence, the basin is proposed as a socio-ecosystem given the intrinsic characteristics to provide water for different uses, these being affected by climate change, making an analysis of the vulnerability of supply basins in presence of climate variability from a critical approach of the problems in the region in terms of management.

Before speaking of integrated management, it is important to refer to the benefits that populations receive from nature – ecosystem services (ES); according to the proposal of the Millennium Ecosystem Assessment –MEA, different approaches are unified and transformed as SE providers. In addition, three categories of services are proposed: provisioning, regulation and cultural [(1–4)]. Water regulations are vital for human well-being; they come directly from ecosystems, without undergoing transformation processes, such as water. The regulation of the hydrological is one of the services with the highest global impact. Its alteration directly affects the most vulnerable populations that depend on this service to obtain drinking water [(5)]. The identification, use and regulation of these services is not a simple issue to address. It is necessary to consider production and consumption patterns, which must be compatible with actions to sustain biodiversity and ecosystems. This situation involves political, social, academic and economic sectors, in search of contributions and alliances that really contribute to the development of management systems that are correctly installed in the current productive dynamics, whose reality is based more on an economic than an environmental sense, being an aspect of relevance in all sectors. Agreements, policies, communiques and others tools have been developed from diverse authorities in search of a better understanding and management of water. The main objective of

the present article is to make a critical review of some of the most relevant aspects in the integrated water management at a global and national level.

2. Methodology

Integrated Water Resources Management – IWRM and National Policy for Integrated Water Resources Management – NPIWRM

Hereafter, are related the main milestones of the constitution of the concept of Integrated Water Resources Management worldwide, reviewing since what happened in Stockholm in 1972 until 2000, when Global Water Partnership –GWP made a definition of the concept (Figure 1). Subsequently, an analysis about what happened in Colombia is made.

As of the United Nations Conference on the Human Environment - (UNCHM), held in Stockholm in 1972, the need for adequate water management has been manifested; evident through the principles 2, 4 and 5 that promoted the establishment of the World Commission on Environment and Development in 1983, where the report "Our Common Future" was issued in 1987 [6]. In this report, sustainable development was presented as the common principle that guides the pursuit of welfare of the nations, establishing the United Nations Environment Programme and at a later time, the publication of the report of the World Commission on Environment and Development (1987).

From the specific point of view of water management, the International Conference on Water and the Environment – ICWE, that took place in Dublin in 1992, promoted dialogs between experts (governmental and non-governmental) to propose four fundamental principles that guide the integral management of water as a concept, as of understanding the multiple uses of water, the synergies that exist between them and the welfare of the communities. These are: i) Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment, ii) Water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels, iii) Women play a central part in the provision, management and safeguarding of water, iv) Water has an economic value in all its competing uses and should be recognized as an economic good [7].

Afterwards, in the United Nations Conference on Environment and Development, held in Rio de Janeiro in 1992, was when the name of Integrated Water Resources Management –

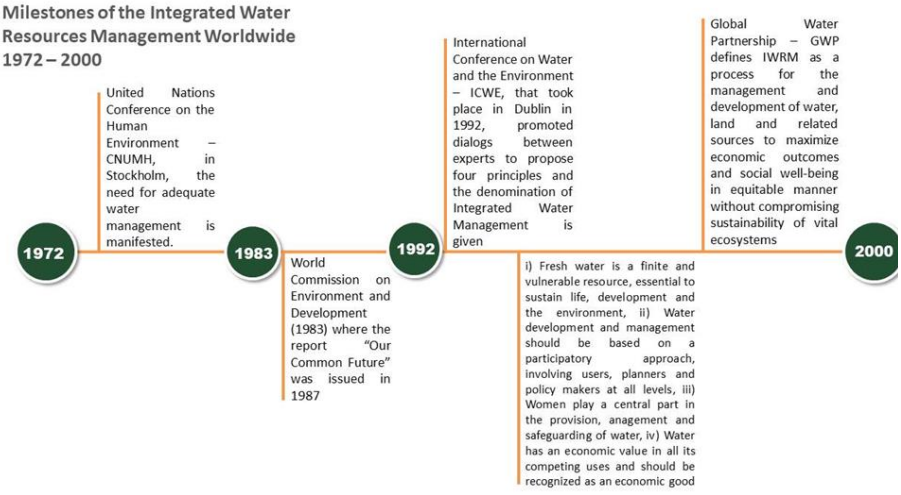

Figure 1. *Milestones of the Integrated Water Resources Management worldwide.*

IWRM was given to the process that was already being discussed some time ago, given its practical implications. In this respect, around the year 2000, Global Water Partnership – GWP defined IWRM as "a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" [(8)], understanding sustainability as principle that refers the ability that socio-ecosystems have to keep in time a dynamic of well-being, which results from the balance and complementarity between ecological, social, institutional and immaterial objectives on defined spatial and temporal scale [(9,10)].

In Colombia, under the influence of the Rio Conference (1992), the United Nations Declaration on Environment and Development was adopted, welcoming the guidelines generated in the area of water resources management. With the issuance of Colombia's general environmental law in 1993, the Ministry of the Environment, now the Ministry of Environment and Sustainable Development, was created as the governing body of Environmental Policy and the National Environmental System - SINA is organized. Subsequently, the competencies and responsibilities of the institutional actors related to water and sanitation were organized, the use of elements of nature was regulated, and government intervention in regulatory, inspection, and surveillance functions was defined by Law 99 of 1993 and Law 142 of 1994 [(11)].

Afterwards, the National Development Plan (PND) (2006-2010) incorporated for the first time a specific component of Integrated Water Resources Management IWRM, which proposed the formulation of a national policy based on international experiences in the framework of Sustainable Development. In addition, this policy establishes unified guidelines about water management, aimed at solving the problem of water resources, making efficient use of water and preserving it as natural heritage for the well-being of future generations. Its specific objectives are: i) To conserve the ecosystems and hydrological processes on which the water supply for the country depends, ii) to characterize, quantify and optimize the demand for water in the country, iii) to improve the quality and minimize contamination of the water resource, iv) to develop integrated management of risks associated with the supply and availability of water, v) to generate conditions for institutional strengthening on integrated water resources management and vi) to consolidate and strengthen the governance for the integral water resources management [(12)].

Nevertheless, the scenario does not seem to be so encouraging despite the proposed objectives due to the fact that river basins such as Cauca River are increasingly exposed to contaminants from agrochemicals used in crops of various products, mining, in addition to facing the pollution produced by human settlements. This situation not only affects water but it can also produce different diseases on people who use it. In this context, despite the fact that the guidelines are focused on the protection, care and maintenance of resources, the reality establishes a different scenario, in which social and state efforts do not seem to respond at the same speed as damage occurs, as stated by the Institutional Network on Climate Change and Food Security (Red Institucional del Cambio Climático y Seguridad Alimentaria) [(13)].

3. Results and discussion

Adaptive Management- Resilience-Governance

Three fundamental concepts can complement IWRM, as a central approach that promotes multiple convergences from the academic field to strengthen the systemic approach required in water management under the premise of sustainability are: adaptive management, resilience and governance (Figure 2).

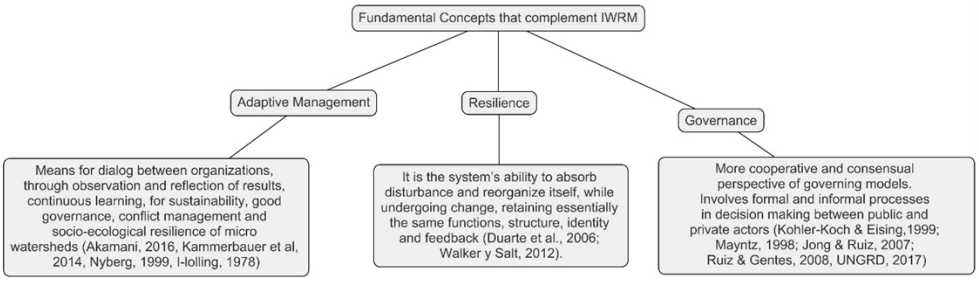

Figure 2. *Fundamental concepts that complement IWRM.*

When referring to IWRM, it is important to mention aspects of the relationship human being-nature from the systemic approach. In this regard, Joaqui [(14)] states that the relationship between society and nature is mediated by the services offered by the ecosystems, extractives and production dynamics at artisan and industrial level, where man interacts with the natural system through management processes [(14)], in which can be evidenced in governance, local scientific learning, frontiers of knowledge and the expression of knowledge; the socialization and diffusion of this relationships is carried out from existing social networks and is based on the confidence for the management of the system, on behalf of the institutions and communities. Thus giving rise to the society-network articulation called socio-ecosystem [(15,16)].

Adaptive Management

In this respect, a reflection about the concept of adaptation will initially take place; according to Joaqui [(14)], adaptation is the capability with which the ecosystem generates alternatives that allow its components to harmonize or adapt processes to the environment [(14)]; the Intergovernmental Panel of Experts about Climate Change – IPCC defines adaptation as the reaction to climate change, which allows the system to adapt to change by decreasing potential damage and seizing opportunities [(17)].

In this order of ideas, maintaining the capacity to absorb disturbances without suffering changes in the structure or function of the socio-ecological systems depends on the capacity of adaptation, expressed in other way, is the capacity of renew or reorganize oneself in the face of change [(18,19)], for this reason, systems with high capacity of adaptation can be reconfigured in the face of changes without significant decreases in the essential functions of the socio-ecological system [(20)]. The latter, understood as a mixture of relationships around resources that are necessary for the adequate development of human beings' lives, in which not only environmental factors intervene but also social and institutional factors [(21)]. This way, it is necessary to emphasize that its base is not centered in the identification of ecological problems but of the interactions that in this field are established with the group of humans in specific environments.

When talking about the capacity of systems to adjust to change, it is also necessary to treat elements of how to do it. In this respect, the concept of adaptive management emerged for the first time in 1978 [(22)], and it is based on the

implementation of policies in an experimental way, since the results of the implementation of policies are unpredictable, This, as a methodological innovation within the management of resources [23].

Adaptive management recognizes that a lot of management policies and activities are actually experiments because their results are not predictable. In this process, experimentation is carried out in various ways to reveal unknown links between management actions and system responses or outputs. This is achieved by combining scientific research concepts and management protocols. The results are tools that can help solve a lot of problems that are unfeasible under other scenarios [24].

Along this lines, the Tropical Agricultural Research and Higher Education Center – introduces the adaptive co-management model, which makes easier the meetings and dialogs between local authorities, grassroots organizations, national organizations with local links and other groups of interest, such as private companies, development organizations and universities, in order to develop agendas for shared actions with effective participation, the empowerment of the actors according to their responsibilities and interests, the efficiency in the allocation of human and financial resources in a way that generates positive impact, tangible and measurable on the quality and quantity of water and in general, on the quality of life [25].

Both approaches to adaptive management recognize co-management of communities, address the no linearity of socio-ecological systems and the need of employ multiple approaches aimed at improving the quality of life of the inhabitants, as well as the basins through observation and reflection of results, continuous learning, feedback and readjustment of methods, in light of the knowledge acquired through reflected action.

According to Kofi Akamani [26] adaptive management of basins has four characteristics (attributes): i) Integration of human being and nature as of sustainable dynamics that allow collectives to subsist without affecting environmental resources; ii) dialogues of knowledge; iii) articulation of particular objectives; iv) involvement of external actors in decision making. In this sense, adaptive management can contribute to sustainability, good governance, conflict management and socio-ecological resilience [26]. These aspects are of interest for the approach of the management of vulnerability since they complement gaps in IWRM, specially the approach to basins such as socio-ecosystems, the effective articulation of multiple actors according to their roles and collective learning as differential aspects to manage vulnerability in supply basins.

Resilience

Ecosystems undergo irregular cycles of organization, growth, collapse and renovation [18]. Therefore, in order to interpret the dynamics of a particular system such as the case of supply basins from the point of view of their management and handling. The conditions of resilience must be defined: understanding it as the capacity that socio-ecological systems have to withstand disturbance [27,28]; the concept of resilience starts from the recognition of continuous change of the systems, as an strategy to manage the capacity that the socio-ecological systems have to confront, adapt and change. Thus proposed, resilience should be understood as the system's capacity to absorb disturbance and reorganize itself, while experiencing change, retaining essentially the same functions, structure, identity and feedback [29,30].

Additionally, resilience involves maintaining options for a rapidly changing environment, where surprise is constant, facing an unpredictable future, so resilience has a look to the future [15]. Resilience and vulnerability have opposite but complementary meanings [31]. So change in a resilient system has potential to create opportunities for development, innovation and self-organization; on the contrary, in a vulnerable system the level of adaptability is reduced and the possibility of transforming itself in order to last over time.

In this context, it can be argued that an ecosystem with low resilience is susceptible to external disturbances and is prone to a variety of tensions and changes. Its low adaptive capacity prevents it from reducing the damage it may suffer in the future; managing ecosystems resilience has implications for human's society livelihood, vulnerability, security and conflicts [31–35]. To quantify the resiliency capacity of a system in the event of a disturbance could open important paths to the comprehension of adaptive cycles of systems [30,36] and contribute to the reduction of spaces that exist in the conceptual gaps for understanding resilience and adaptation in the framework of socio-ecosystems. Although it must be stated that resilience may not be unlimited because some man-made damage may be irreparable, reaching a point of no return, in which a given environment is no longer capable of recovering its initial natural characteristics and will be transformed into another type of environment. This makes resilience an option in the face of the development of environmental actions, but does not ensure in all cases positive effects.

Thus, scientists point out that it is very difficult to know when that capacity of nature is exceeded. The elements that influence resilience are complex: the water cycle, fertility, biodiversity or climate interact with each other and affect different systems. More research is therefore needed.

Governance

As Mayntz has pointed out: "governance is now frequently used to indicate a new way of governing that is different from the hierarchical control model, a more cooperative way in which actors participate in mixed public-private networks" [37]. Governance is characterized by adopting a more cooperative and consensual perspective than the one used in traditional models of governing [38-40]. It involves formal and informal processes in decision making between public and private actors with similar or opposite interests [40,41].

In this sense, governance is related to a certain degree to the model of networks involving different actors whose interaction is crucial to face problems and tends towards a change in the exercise of public administration through coordination and organization of a deliberative space, based on trust, participation and social control [42]. It is the ability in the shared design of public policies and socially accepted institutional structures [42,43].

For this reason, and given that socio-ecological systems are not linear or predictable, the implementation of management strategies to face change must be creative, flexible, coordinated and concerted and with local learning capacity. It is therefore important to consider the conditions to stablish water governance, promoting decentralization and dispersion of power between governmental and non-governmental bodies [42,44]; seeking to increase social participation without exclusions; share responsibility for water conservation; multiply the value of transparency and communication in the network of factors; and establish a regulatory

regime that equitably includes diverse social needs and interests [45].

Basin as an socio-ecosystem

Socio-ecosystems – SSE can be considered as complex adaptive systems because they present attributes such as historical trajectory, non-linearity, uncertainty, hierarchies and emerging properties [15]. In the SSE, nature, society and institutions are integrated as a whole that interact dynamically in time and space in different scales [9,16], conforming adaptive and self-organizing systems [46]. On the other hand, a basin is cataloged as a geographic unit that usually gathers several ecosystems where families inhabit and manage the available resources, mainly soil, water and vegetation for their daily activities. Man uses the goods and services that this unit provides for his welfare [47,48].

As a consequence, social systems and ecosystems are closely linked and therefore the exclusive delimitation of an ecosystem or a social system is arbitrary and artificial [46]. The ecological and social link is mediated by the services that ecosystems offer; in SSE the human dimension is related the natural system through management processes, where social networks play an important role since they underpin the trust required between different actors for the management of the system [3,15].

So, basins are understood for the present study as a socio-ecological system because they are a space where natural and social resources interact in a permanent and dynamic process through organizations, projects and/or worldviews [49]. In addition, it will have as a framework for the management of water resources, defined under a social, economic and operational approach and also a territorial and hydrological approach traditionally used [47,50,51].

Vulnerability of supply basins to climate variability

According to Adger [52], vulnerability is the state of susceptibility to damage from exposure to stresses associated with environmental and social changes and lack of adaptive capacity. Therefore, the analysis of vulnerability and resilience have common elements since both address the diverse effects and tensions experienced by the socio-ecosystem [52], with the capacity to adapt being the decisive response of SSE to the tension that should be managed.

On their behalf, the Intergovernmental Panel on Climate Change – IPCC defines vulnerability as the extent to which climate change can adversely a system; and it depends on: i) sensitivity, and ii) its capacity to adapt to new climatic conditions [17].

Additionally, the IPCC [53] recognizes that vulnerability is dynamic and specific according to the context in which it is studied and ruled by the behavior of the human being and the organization of society itself. This influences on the susceptibility of the population and will depend of its adaptation to threats, the latter referring to the capacities that allow a system to protect itself when facing different adversities in a long-term process that involves adjustments in the system itself and includes learning, experimentation and change [53].

According to Valencia et al. [27] the conceptualization of vulnerability in recent years has gone from a vision that only takes into account one discipline to a multi-disciplinary vision, in which areas of knowledge are integrated until an interdisciplinary approach is taken to the components of the socio-ecosystems. The development of methodological analysis procedures emerges from their transdisciplinary approach [27]. However, most

analysis models are aimed at understanding social vulnerability and in some cases include biophysical vulnerability to a specific threat and are traditionally approached from engineering, geography and social sciences.

As a result, in recent years, increasing attention has been paid to the analysis of vulnerability of the socio-ecological system (basin) to the loss or degradation of ecosystem services (in the case of the water supply ecosystem service). The conceptual framework for the evaluation of social and ecological vulnerability addresses three challenges: conceptually differentiate between a threat, exposure and sensitivity of both the ecological and social system; consider the characteristics of the beneficiaries including aspects such as type of need that is satisfied, uses of water, availability of mechanisms and/or tools for access and perception of the beneficiaries in the event of threat [54].

4. Conclusions

Analysis of the situation in the context of the territory

In synthesis, taking as a reference what has been proposed, vulnerability depends on: i) sensitivity, ii) its capacity to adapt to new climatic conditions; iii) the relevance of policies and iv) the disciplinary approach for its analysis. The analysis of vulnerability has to do with governance and risk management, which are in common ground with adaptation and resilience.

Thus proposed, in Colombia the dialogue about vulnerability of water begins with the Third Assessment Report of the IPCC: Climate Change 2001, where vulnerability is established as the result of three components: exposure, sensitivity and adaptation capacity. From this approach, several approximations have been made to vulnerability of basins, under a systemic approach, understanding the supply basin as a socio-ecosystem, which allows an integral understanding of the conflicts and interrelations between human being and natural systems.

In addition, as essential elements for vulnerability analysis, it is important to refer the biophysical factors that determine the availability of water in the supply basins. These are: temperature, precipitation, evapotranspiration, soil cover and other social types such as uses and customs associated to water, which vary by region. In this context, for Colombia, according to the Institute of Hydrology, Meteorology and Environmental Studies, it is projected that in 2071 – 2100, the average precipitation will decrease between 10 and 30% in about 27% of the national territory (Amazonas, Vaupés, south of Caquetá, San Andrés and Providencia, Bolívar, Bolivar, Magdalena, Sucre and northern Cesar). However, for the same period, precipitation is expected to increase between 10 and 30% in about 14% of the national territory (Nariño, Cauca, Huila, Tolima, Eje Cafetero, western Antioquia, northern Cundinamarca, Bogotá and central Boyacá). This variability in rainfall and changes in land use would increase the probability of events such as landslides, effects on countryside aqueducts and supply systems and damage to road infrastructure in mountain areas.

On the other hand, as a contribution to know the state and dynamics of water in the country, the Institute of Hydrology, Meteorology and Environmental Studies – IDEAM, through the National Study of Water – ENA of 2014, identifies that in Colombia, the sources of water supply are mainly superficial. It also states that 40% of the main supply basins are vulnerable because due to climate variability. That is, possible climate variations affect the basins in terms of its ability to conserve and maintain hydrological regime, which is directly related to the supply and availability of water for human consumption.

In this sense, the affectation of the climatic variability for the regions of the southwest of the country like the department of Cauca has been noticeable, impacting the territory negatively in the last years because of the presence of climatic phenomenons like La Niña (2010-2011) and El Niño-Southern Oscillation (2015-2016). In this respect, according to the departmental water plan of the cauca, it is worth mentioning that in 2015, 25 of the 42 municipalities of the department were declared in public calamity due to events that mainly affected the infrastructure of the aqueduct, impeding the provision of water supply for human consumption. An example of this is the municipality of Timbio, whose supply basin, the Timbio River, has registered flooding, drought and avalanche. Added to this, the anthropogenic activities have been the main causes of environmental degradation given the intense deforestation in the riverside areas.

The posed situation shows a problem in the supply sources of socio-environmental character, associated to the following causes: deficient and/or decontextualized analysis of vulnerability due to water shortage in the face of climate variability; little or no environmental monitoring of basins; ineffective coordination activities at the municipal level between environmental authority, territorial entity and social organizations for the integral management of water; limited self-management capacity due to low level of knowledge of the risk of water shortage in the territory; no adaptive approach to basin management has been considered, that is, a process through which practices and dynamics are systematically improved by learning from the results of the management strategies already implemented, in which key actors from the social and governmental sectors are involved as a mechanism for reducing the risk of water shortages; difficulty in the application of regulations that govern the drinking water sector, taking into account the realities of the territory; need for a risk management approach to the management and control of water deficit, which considers the practices, uses and customs that society assumes towards the water resource, for its care and protection.

The above mentioned problem is related, on the one hand, to the water deficit that generates problems of availability, shortage and rationing with its consequent harmful effects on the quality of life of the population and its economic activities; in addition to negative environmental impacts on soil, flora and fauna; although the greatest use of water is for agricultural activity, the most critical aspects of availability are related to the supply of water for consumption, for industrial processes and for the production of electrical energy. On the other hand, excess of water causes floods, avalanches and/or landslides that affect the water supply because they pollute water sources with sediments and can destroy the water supply and distribution systems. It also generates direct impacts on the availability, continuity and quality of water to be supplied, in addition to the economic costs implied by water losses, recovery works, rehabilitation and reconstruction of water supply systems.

For this reason, it is necessary to refer initially to the Integrated Water Resource Management – IWRM, this configured as a tool for the development and management of water, seeking a balance of environmental, economic and social needs. However, its implementation is done from the institutional framework that requires political will and support of the competent authorities, which has hindered the efficiency of IWRM. This situation does not benefit the self-management of water in the territory to address the complexity of environmental issues emerging from climate variability.

This puts in the discussion framework the real needs of establishing an adequate balance between environmental, social and economic,

despite the urgency of evaluating the characteristics and conditions of basins, in order to project their care and ensure their permanence, reality implies uniting disparate sectors such as economy and society. The first of them is oriented to agricultural and industrial expansion. The second is oriented to the well-being of human group that are increasing. This way, it is necessary to consider the current reality in terms of consumption and production patterns, generating a balance that does not set the parts against each other.

Finally, and as a conclusion, it can be stated that from the academy and government institutions, analysis of vulnerability of supply basins have been carried out in the department of Cauca, from an interdisciplinary approach that integrates the social, biophysical, economic, cultural, legislative and infrastructure dimensions, related to the supply, quality and demand of water. This indicates an approach to systemic analysis; these studies have been carried out with an emphasis on urban supply, taking into account adaptation capacities. On the other hand, the Corporación Autónoma Regional del Cauca – CRC has made approaches for the vulnerability analysis of supply basins with a methodological approach that addresses the biophysical and social dimensions regarding the effect that this can produce in human groups. However, they do not take into account the community's perception of water management in the analysis. None of the approaches considers a model for the management of vulnerability of the country side basins that allow the generation of strategies to reduce this vulnerability, from the appropriation of knowledge and strengthening of endogenous capacities of the territory.

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