Chapter 5

Integrated water resources management

Azeneth Eufrausino Schuler
Jorge Enoch Furquim Werneck Lima
Marcus Aurélio Soares Cruz

Introduction

Target 6.5 of SDG 6 – implement integrated water resources management at all levels – is the subject of this chapter and is discussed in four topics. The introduction topic presents a general explanation on the concept, implementation and tools of integrated water resources management (IWRM). The second item deals with the conditions and instruments needed for the implementation of IWRM and how they have been applied in Brazil. The third presents the challenges to be overcome and some examples of contributions from Embrapa to the implementation of IWRM. The fourth and last topic shows a reflection on future perspectives to increase Embrapa's contribution to the implementation of integrated, participatory and decentralized water management giving support on science, technology and information.

The concept of integrated management has been developed throughout history, incorporating new meanings since the last decades of the 20th century, when the increase of environmental problems on the Earth led to the proposition of sustainable development goals (Report..., 1987; Snellen; Schrevel, 2004). The Global Water Partnership (Integrated..., 2000, p. 22) presented the following definition of IWRM:

> IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

In order to implement integrated management, it is necessary to develop an adequate environment with legislation, policy and management plans besides an institutional infrastructure in which tools, rules and stakeholders' roles are well defined. The IWRM advocates social participation through monitoring and evaluating water management applied in the smallest possible territorial

unit identified as a river basin. Strategies for capacity building management monitoring should be established, implemented and constantly updated. Management evaluation should be based on indicators selected to demonstrate the progress of the measures adopted and their effects on the quality of water system management.

Integrated management of water resources

According to Status... (2012), IMWR proposes some conditions for its viability, as:

- Cross-sectoral management and consideration of multiple uses of water.
- The development of an enabling environment of management.
- The decentralization and participation of the different actors involved.
- The creation of institutional infrastructure: legal framework and roles definition.
- An information system on water resources for sharing.

In Brazil, the legal and institutional framework to create an enabling environment for IWRM was established by the Política Nacional de Recursos Hídricos (National Policy of Water Resources – PNRH), Law 9,433/1997 (Brasil, 1997), known as the Lei das Águas (Water Law). This policy was based on the IWRM principles enrolled in United Nations (UN) documents: The Dublin Statement (International Conference on Water and the Environment, 1992) and Agenda 21 (United Nations Conference on Environment and Development, 1992). The fundamentals of the PNRH (Brasil, 1997) are:

- Water is a public good.
- Water is a limited natural resource endowed with economic value.
- Under scarcity conditions, the priority water use is the human and animal supply.
- The management of water resources should always provide multiple use of water.
- The water basin is the territorial unit for the implementation of PNRH and the Sistema Nacional de Gerenciamento de Recursos Hídricos (National System of Water Resources Management – Singreh).

- The management of water resources should be decentralized and involve the participation of government, users and communities.

The objectives and general guidelines of the PNRH make clear reference to the integrated management of water resources as well as the needs of the current and future generations. The Law of Water, or Law 9,433/1997, also established instruments for the management of water resources and created Singreh with integrated, decentralized and participatory management as its guideline. The decentralizing character of the PNRH was expressed by the creation of a national system that integrates the federal government and states. The participatory character of this system requires the installation of river basin committees, in which the federal, state and municipal authorities, water users and civil society operate.

The instruments of integrated management of water resources are (Status..., 2012):

- Evaluation of water resources (monitoring networks, assessment techniques and environmental impact studies – EIA).
- Communication and information to enhance the awareness of decision makers.
- Instruments of water allocation, cost and benefit assessment and conflict resolution.
- Direct regulatory instruments (master plans of use, regulations, etc.) and economic instruments (prices and tariffs, taxes, subsidies, incentives, fines, etc.).
- Technology (research and development, guidelines for evaluation and selection of technologies).
- Public and private financing of IWRM considering its high rate of return for society.

In Brazil, the PNRH established the following management instruments (Brasil, 1997):

- The water resources plans of states and basins.
- The classification of bodies of water into classes, according to the predominant water uses.
- The granting of rights to water use.

- The charging for the water use.
- The compensation to municipalities.
- The Sistema de Informações sobre Recursos Hídricos (Water Resources Information System – SIRH).

In addition to these instruments, Law 9,433/1997 defines Singreh and the roles of stakeholders that participate in the systems instances:

- The Conselho Nacional de Recursos Hídricos (National Council of Water Resources – CNRH).
- The Agência Nacional de Águas (National Water Agency – ANA).
- The Water Resources Councils of the States and the Federal District.
- The River Basin Committees.
- The federal, state, Federal District and municipal institutions related to the water resources management.
- Water Agencies.

The creation of an information system for compiling, organizing and sharing of water resources data is one basic requirement for integrated management. The PNRH law established the Sistema Nacional de Informações sobre Recursos Hídricos (National Information System on Water Resources – SNIRH), defined as "[...] a system for collecting, processing, storing and retrieving information on water resources and factors involved in its management" (Brasil, 1997, art. 25, our translation). Its principles include the decentralization of the collection and production of data, the coordination of the system and the guarantee of access to data and information to all members of society.

Challenges to reach IWRM and the contributions of Embrapa

Since the publication of Law 9,433/1997 (Brasil, 1997), there has been much progress in the institutional framework to IWRM, including the creation of the National Water Agency (ANA) by Law 9,984/2000. ANA is responsible for implementing the National Policy of Water Resources (PNRH) and the federal water resources management. The agency also integrates the National System of Water Resources Management (Singreh) (Brasil, 2000).

Considering the IWRM demands for cross-sectorial action and for integrated water and land management, Embrapa offers fundamental contribution to development of knowledge and technology in the agricultural sector, which also includes forestry production, fishery and aquaculture.

Agriculture accounts for 54% of total water withdrawals (Conjuntura..., 2017) with impact on water resources even in a scenario where rain-dependent agriculture is predominant. ANA's annual report on water resources, *Conjuntura das águas* (Conjuntura..., 2017), points out that total water withdrawals for the different sectors reached 2,057 $m^3 s^{-1}$ in 2016, while consumption was 1,081 $m^3 s^{-1}$, calculated as the difference between the withdrawals and the return water volume. The agricultural sector accounts for 78% of this total consumption, 67% for irrigation and 11% for animal supply. The difference between agriculture participation in water consumption and withdrawals is due to the low return volume from irrigation diverted water as a greater part is used evapotranspiration.

According to the management adopted, the farming systems can be either detrimental or beneficial to water services in terms of quality, availability and habitat for biodiversity. As an agricultural research institution, Embrapa aims at the generation of technologies for the sustainable management of production systems, improving the integrated management of land and water resources. A set of these technological contributions to reach IWRM are grouped according to five challenges presented in the report *Conjuntura 2017* (Conjuntura..., 2017), as follows.

Environmental management

Considering the conflicts between the demands of the user sectors and the environmental agenda, one of IWRM challenges is to improve the integration of water resources management with this agenda through seeking the internalization of concepts such as sustainability, ecosystems and ecosystem services by economic sectors. The main technological contributions developed by Embrapa to cope with this challenge are the following:

- The ARAquaGEO tool: spatial analysis of the environmental risk of water contamination.
- Monitoring and quali-quantitative characterization of rural basins (The AgroHidro Project).

- Characterization of hydrological behavior and parameterization of models applied in different Brazilian biomes (The SWAT-Cerrado Project and Rede Nacional de Bacias Experimentais e Representativas – National Network of Experimental and Representative Basins – ReHidro).
- Spatially explicit approach for mapping ecosystem services and assessing environmental impacts including water-related services and impacts (MapES).
- Payment for environmental services: monitoring and selection of areas.
- Diagnosis of suspended sediment flow in Brazilian rivers.
- Methods of drinking water treatment for rural communities of the Brazilian semiarid region (Sodis).

Demand-side water management

The practices of rational use of water, loss reduction, demand control and water management by the agricultural sector have gained valuable contributions from Embrapa through decision support models and other technologies to an efficient use of water in agriculture. Some of these contributions are listed as follows:

- Mapping of irrigated areas in Brazil.
- IrrigaWeb: online training on the use and management of irrigation.
- Low-cost irrigation management for family farming in the semiarid region.
- Rede de Agricultura de Precisão (Precision Agriculture Network): technological development to improve accuracy and efficiency in the use of water, soil and inputs by agriculture.

Water security and risk assessment

The concept of water security has raised challenges related to the commitment ensuring water for human supply and productive activities in a sustainable way, such as reducing the risks of critical events of droughts and floods associated with climate change and variability. The main technological solutions proposed by Embrapa are:

- Impacts of climate change and agriculture on water resources in several biomes (AgroHidro Network and the Chuva-Vazão/Rainfall-Runoff Project).
- System of water sustainability indicators for sugarcane.
- Geo-Hidro Pantanal: online hydrological information of the Upper Paraguay River-Pantanal Basin; local news on flood risks to allow the planning herds movement.
- Zoning of water availability and demand for agriculture in the *Cerrado* biome (The Rainfall-Runoff Project).
- Zoneamento Agrícola de Risco Climático (Agricultural Zoning for Climate Risk – ZARC).
- Agroecological zoning, including the land suitability for irrigation.
- Sistema Brasileiro de Classificação de Terras para a Irrigação (Brazilian Land Classification System for Irrigation – SiBCTI).
- Underground dam: rainwater harvesting and storage technology for food production.
- *Barraginhas* (Small Dams).
- Simulation of regionalized climate change in semiarid fruit crops, impacts and adaptation.
- Rural cisterns.
- Rainwater harvesting in situ.

Groundwater

Referring to the integration between surface and groundwater management, Embrapa has results that can contribute to the mitigation of the agriculture impacts on the groundwater and territorial planning improvement in aquifers zones. The main technological contributions/solutions are as follows:

- ARAquá 2014 – ARAquá – Environmental Risk Assessment of Pesticides.
- Numerical simulation of organic contaminants in soil and water (Paraíba; Pulino, 2003).

Enhancement of the participatory process

Several committees have been installed in the Brazilian river basins although many have operational constraints, as well as problems of representativeness. Embrapa has been invited to participate in several instances of Singreh to provide knowledge-based information and technological solutions to handle the water use conflict resolution. Some ways of Embrapa contribution to the participatory process in IWRM are as follows:

- Participation in the National Council of Water Resources (CNRH), in water councils of the states and the Federal District and in the river basins committees of basins (CBH), such as the CBH Paranoá, Guanabara Bay, Jaguaribe River, sub-basins of Preto River, etc.).
- Application of participatory methodologies and knowledge building approaches in rural river basins focused on soil and water conservation and improved management of farming systems.

Final considerations

Considering the challenges pointed out in the report *Conjuntura...* (2017) and current contributions from Embrapa to water management in agriculture, one can find many opportunities for agricultural research to improve IWRM.

As a management tool, water resources plans must be formulated for states and basins and may count on an effective contribution from Embrapa. The studies to characterize basins in terms of territorial, ecosystem and biogeochemical dynamics, as well as the production systems make available important information for the development or review of the Basin Plans by the committees. An example of this contribution is the Programa Nacional de Solos (National Soil Program – PronaSolos), under the coordination of the Ministry of Agriculture, Livestock and Food Supply (Mapa), which has Embrapa as executive branch through Embrapa Soils, the Unit responsible for research and development in soil science. With a national network of research institutions, PronaSolos will produce information and soil maps in scales compatible with the land use planning throughout the country territory, starting with selected priority areas. Many of these areas are river basins responsible for water supply to populations and productive sectors. Soil maps on compatible scales for the elaboration of Basin Plans is an old demand of the water resources sector.

The National Information System on Water Resources (SNIRH) also provides a wide range of collaborative opportunities. For exemple, the SNIRH infrastructure may integrate information about technologies and knowledge on water resources produced by Embrapa research groups, such as the AgroHidro Network and the project portfolios on Climate Change, Drought Management, Irrigated Agriculture and Aquaculture. Available results from these projects are useful to inform and train representatives of civil society, water users, farmers, water management staff in public service, government authorities, members of Ministério Público Federal (the Public Justice Service) and the population in general.

Sharing information and knowledge about water and agriculture management technologies contributes to capacity building and enhancement of members' participation in water resources committees and councils. Joint actions for training promoted by Embrapa, ANA, the water management institutions, the basins committees, the universities and civil society cooperate to an IWRM enabling environment. This is essential for decentralized, participatory and knowledge-based management.

References

BRASIL. Lei nº 9.433, de 8 de janeiro de 1997. Institui a Política Nacional de Recursos Hídricos, cria o Sistema Nacional de Gerenciamento de Recursos Hídricos, regulamenta o inciso XIX do art. 21 da Constituição Federal, e altera o art. 1º da Lei nº 8.001, de 13 de março de 1990, que modificou a Lei nº 7.990, de 28 de dezembro de 1989. **Diário Oficial [da] República Federativa da União**, 9 jan. 1997. Available at: <http://www.planalto.gov.br/ccivil_03/Leis/L9433.htm>. Accessed on: Feb. 8, 2018.

BRASIL. Lei nº 9.984, de 17 de julho de 2000. Dispõe sobre a criação da Agência Nacional de Águas - ANA, entidade federal de implementação da Política Nacional de Recursos Hídricos e de coordenação do Sistema Nacional de Gerenciamento de Recursos Hídricos, e dá outras providências. **Diário Oficial da União**, 18 jul. 2000. Available at: <http://www.planalto.gov.br/ccivil_03/leis/L9984.htm>. Accessed on: Feb. 8, 2018.

CONJUNTURA dos recursos hídricos no Brasil 2017: relatório pleno. Brasília, DF: Agência Nacional de Águas, 2017. Available at: <http://www.snirh.gov.br/portal/snirh/centrais-de-conteudos/conjuntura-dos-recursos-hidricos/relatorio-conjuntura-2017.pdf>. Accessed on: Feb. 8, 2018.

INTEGRATED water resources management. Stockolm: Global Water Partnership, 2000. 67 p. (TAC background papers, 4). Available at: <http://www.gwp.org/globalassets/global/toolbox/publications/background-papers/04-integrated-water-resources-management-2000-english.pdf>. Accessed on: Jan. 8, 2018.

INTERNATIONAL CONFERENCE ON WATER AND THE ENVIRONMENT: DEVELOPMENT ISSUES FOR THE 21ST CENTURY, 1992, Dublin. **The Dublin Statement and Report of the Conference**. Geneva: World Meteorological Organization, 1992. Available at: <https://www.ircwash.org/sites/default/files/71-ICWE92-9739.pdf>. Accessed on: Feb. 8, 2018.

PARAÍBA, L. C.; PULINO, P. **Simulação numérica da dispersão-advecção de pesticidas no solo sob efeito da temperatura**. Jaguariúna: Embrapa Meio Ambiente, 2003. 45 p. (Embrapa Meio Ambiente. Documentos, 35). Available at: <https://www.embrapa.br/busca-de-publicacoes/-/publicacao/14527/simulacao-numerica-da-dispersao-adveccao-de-pesticidas-no-solo-sob-efeito-da-temperatura>. Accessed on: Feb. 23, 2018.

REPORT to the World Commission on Environment and Development: our common future. [S.l.]: United Nations, 1987. Available at: <http://www.un-documents.net/our-common-future.pdf>. Accessed on: Feb. 8, 2018.

SNELLEN, W. B.; SCHREVEL, A. **IWRM**: for sustainable use of water: 50 years of international experience with the concept of integrated water management. Wageningen: Ministry of Agriculture, Nature and Food Quality, the Netherlands, 2004. (Alterra-report, 1143). Background document to the FAO/ Netherlands Conference on Water for Food and Ecosystems. Available at: <http://edepot.wur.nl/30428>. Accessed on: Feb. 8, 2018.

STATUS report on the application of integrated approaches to water resources management. Nairobi: United Nations Environment Programme, 2012. 106 p. Available at: <http://www.un.org/waterforlifedecade/pdf/un_water_status_report_2012.pdf>. Accessed on: Feb. 8, 2018.

UNITED NATIONS CONFERENCE ON ENVIRONMENT & DEVELOPMENT, 1992, Rio de Janeiro. **Agenda 21**. Rio de Janeiro: United Nations Sustainable Development, 1992. Available at: <https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf>. Accessed on: Feb. 8, 2018.