water

Article

A New Water Governance Model Aimed at Supply–Demand Management for Irrigation and Land Development in the Mendoza River Basin, Argentina

Mario Salomón-Sirolesi [1,*] and Joaquín Farinós-Dasí [2]

[1] Facultad de Ingeniería, Universidad Nacional de Cuyo, Centro Universitario, Ciudad de Mendoza M5502JMA, Argentina
[2] Departamento de Geografía e Instituto Interuniversitario de Desarrollo Local, Universidad de Valencia.Av. Blasco Ibáñez, 28 (3ª planta), 46010 Valencia, Spain; Joaquin.Farinos@uv.es
* Correspondence: salomonmario@yahoo.com.ar; Tel.: +54-261-4685181

Received: 26 January 2019; Accepted: 27 February 2019; Published: 5 March 2019

Abstract: This study aimed at achieving an organizational solution for improving the governance of water and land use and, consequently, improving the supply–demand water balance. Related modeling applied to diverse scenarios focus on water and land use development in the Mendoza River basin. A strategic analysis of water organization was performed using causal analysis, producing a Strategic Map (SM) and designing a Balanced Scorecard (BS). To assess the basin's water resources supply and demand, the Water Evaluation and Planning (WEAP) model was applied to the Administrative Management Units existing in the basin, taking into consideration the water availability and the granted water rights. The application of the organizational and governance model to various scenarios referring to 2030 show that by reordering allocations and water use criteria, implementing a better farm irrigation water management, improving capacity building of existing human resources, and adopting more adequate hard- and software for dams and canal management, it will be possible to accommodate demand in 2030 better than at present despite climate change impacts on demand and supply. In addition, users' participation will be enhanced.

Keywords: water and land management; water users' organization; water balance; supply–demand balance model; organizational analysis; participatory management

1. Introduction

The water governance model currently used in the Mendoza River basin, Argentina (Figure 1), brings about imbalance and unevenness of management inadequate for an area in full transformation. Spatio-temporal effects of great intensity and magnitude refer to the limited autonomy and self-sufficiency of local management organizations, the inadequate distribution and use of water resources, the separate management of water and land, the impact of territorial, economic, and productive competitiveness, the degradation of soils, all affecting crops production and causing poor service to users [1]. The water management model emerged in the nineteenth century, derived progressively very top–down and technocratic, but functional to the corporate external as well as internal interests. As a result, hierarchical, highly centralized power of decisions does not comply with the principle of accountability. Improved control would be feasible through an administrative decentralization process by watersheds and subareas. The primal social contract for the water administration in Mendoza implemented by the traditional and conservative elite in 1884, in a time of great and rapid agricultural expansion, does not fit well in current conditions; besides, it has caused very negative consequences, difficult to correct, to the territorial–hydrological system. As emblematic cases, demonstrating such trends: a) despite having passed a century since then, it still lacks the implementation of water balances as well as legislative changes facilitating reallocation of water rights; b) loss of water rights in productive areas because use changes from agricultural to recreational ones, affecting the functioning of the system as a whole; c) groundwater overexploitation and speculative use of water resources for more than 40 years, which has caused the loss of the aquifer productivity and quality; and d) failure to consolidate autonomous water organizations for productive local units, according to appropriate monitoring processes.

The consequences of this model's 19th century view, extemporaneous today, affect social, economic, and productive dimensions for not ensuring efficient administration and satisfaction of the demand [2]. Appropriate practices for the sustainable management of water in the basin include real-time water measurement, efficient application of irrigation modules and plans, uniformity in the application of water, clean production associated with water quality, improved land leveling for better performance of irrigation, soil mulching to reduce evapotranspiration, use of adequate irrigation flow rates, monitoring of soil moisture and plant water status, proper design of irrigation units, conservation of drains, and training of water system operators and users [3,4]. Meanwhile, the main issue is to implement a governance model that provides for improved participatory management through local water user organizations.

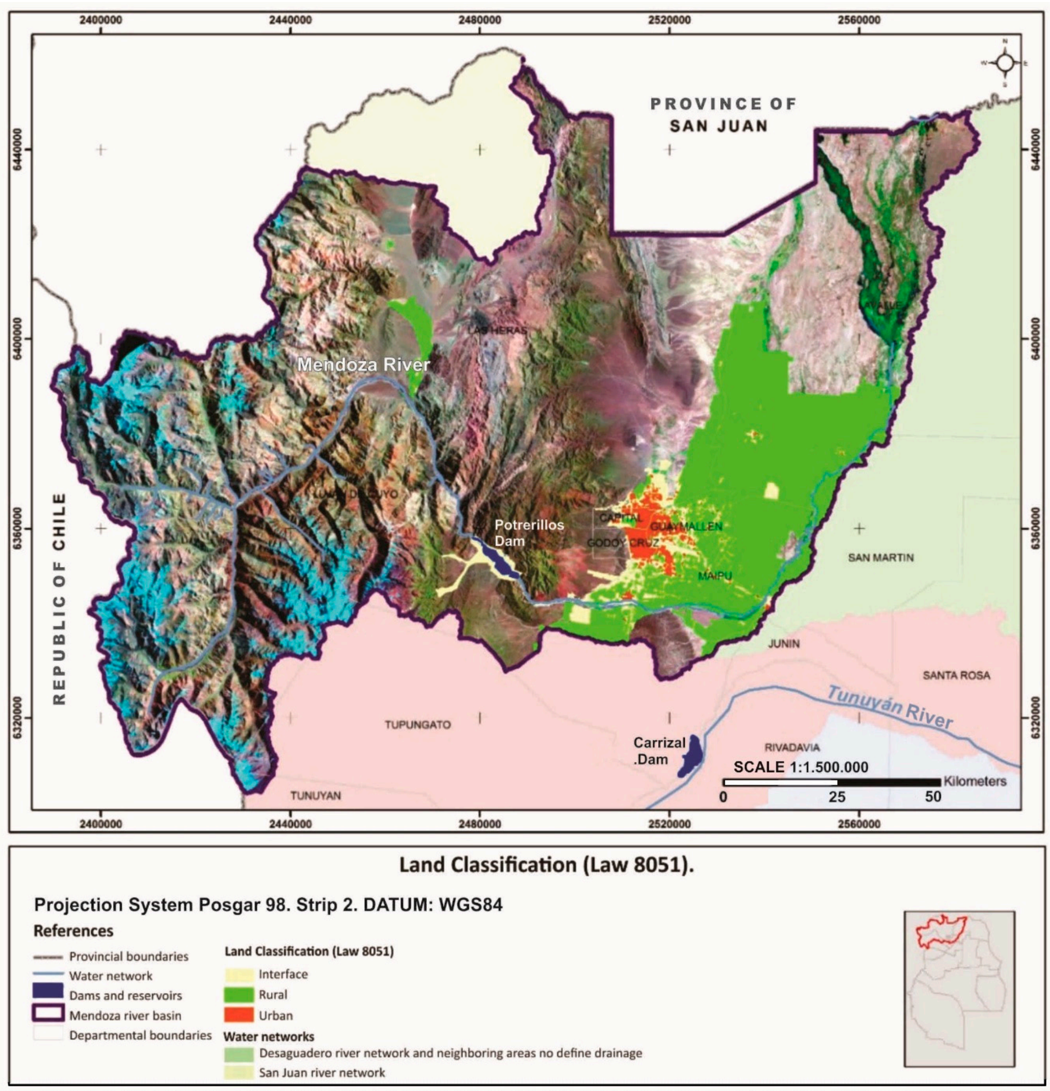

Figure 1. Mendoza River basin [5].

It is worthy of notice that, as part of the decentralization process implemented by the end of the 20th century [6], the Mendoza River Water User Organizations (WUOs) contributed not only to establishing a new governance, but also to the integrated process of regional development, namely evidencing that water management is a critical factor in a semiarid region [7]. WUOs had highly influenced the elaboration of the Land Use Law and the Strategic Development Plan (SDP), the execution of which required an effective supply–demand water balance implementation, restructuring of granted rights, respect for basin autonomy, effective representation and participation of the different water users, and consensual reformulation of the instruments necessary to achieve integrated water management [8]. In this process, there appears that, in the absence of the State, community management and associative modes have been efficient in supplying water at a local scale [9]. Territorial governance is thus a nonexclusive governmental dimension, where public participation influences decision-making and the social and spatial structure of processes involved [10]. Thus, under high social and public control, land and water governance strategies and integrated management services are expected to ensure strategic and productive territorial development [11].

The main objective of this paper was the formulation of a participatory organizational model consistent with current requirements of users, as well as with the water supply–demand balance modeling, in order to reach an equitable and sustainable water resources availability and use in the Mendoza River basin. It is foreseen that the organizational governance proposal will contribute to achieving greater efficiency and effectiveness in the water and land use together with the implementation of the administrative act when considering different prospective modalities relative to various context scenarios. Accordingly, objectives include the identification of strategies to promote the decentralized management of water, namely those referring to the ways in which WUOs may implement water demand management actions based on present supply–demand water balance issues.

The strategic formulation of the governance model was carried out by defining the organizational identity through the determination of the mission, vision, values, and strategies of WUOs. The organizational analysis was developed through the preparation of a strategic map [12] and the linking of the WUOs through the design of the Integral Scorecard (IS) [13]. Secondly, the available water resources of the Mendoza River basin [14] were assessed through updated water balance (WB) studies [15] and the application of the Water Evaluation and Planning model (WEAP) [16]. The latter tool allows contrasting water supply and demand considering a distribution system marked by spatial and temporal variability. An adjusted modeling approach [17] was used for different scenarios according to the peculiarities of the basin relative to each of the basin's Administrative Management Units (AMUs) and considering the availability of water and the granted uses [18,19]. Based on the constitutional law of Mendoza, which previses the water balance and assesses for the reallocation of rights, three scenarios have been considered in water modeling: i) trend, which is to continue with the allocation of water without changing the category of agricultural rights in use and with the current efficiencies; ii) possible, which is to equate the agricultural rights in use and delivery of 100% of the endowment improving the efficiencies, and iii) contrasted, which is to distribute the water with 100% to all the rights registered whatever the use and improving the efficiencies. For this purpose, different criteria for irrigation planning were analyzed [20], irrigation requirements and scheduling were considered [21], and strategies for water management were identified [22].

2. The Study Area

The Mendoza River basin is located in the Andean Central West Region of Argentina, covering an area of 19,553 km^2 with a population of 1,170,000 inhabitants [23]. It includes a densely populated sector corresponding to the urbanized oasis, an intensive irrigated area, and areas of great natural value as well as areas with more extensive uses such as units of mountain range, premountain range, and non irrigated alluvial plains (Figure 1). River flows, namely those aimed at the supply of the urban and irrigated areas, are regulated by the Potrerillos Dam [24].

With the aim to achieve a systematized knowledge of the basin with snow-glacial regime, it must be considered that the main contribution, represented by snowfall, its accumulation–compaction, and freezing–melting phases, generates direct flows complemented, to a lesser extent, with rainfall contributions. These flows cause surface runoff, as well as subsurface and groundwater flows corresponding to the various components of the basin water balance (Figure 2), which must be assessed in order to obtain a comprehensive knowledge of water supply [14].

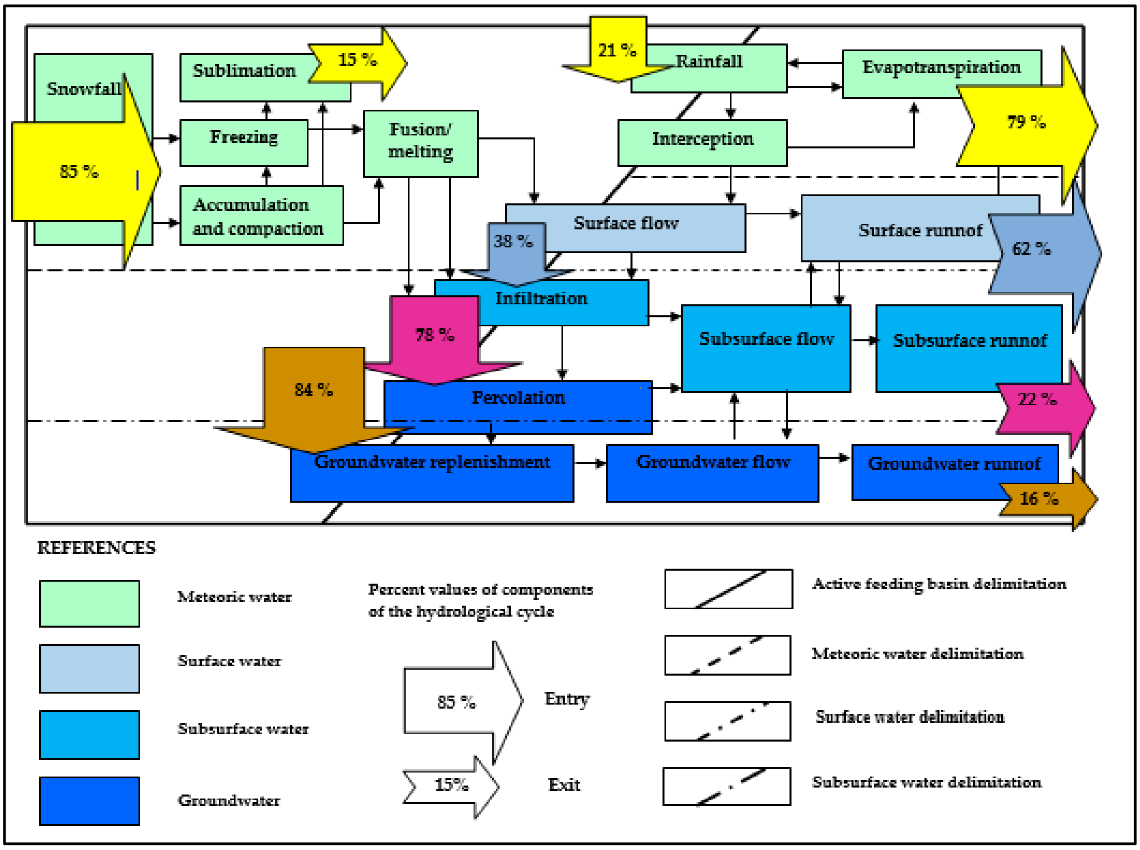

Figure 2. Main water balance components and physical processes in the Mendoza River basin.

3. Formulation of the Organizational Model

The strategic analysis of water organization was performed using the causal analysis method, thus considering that such organization is a constituent part of the development of a continuous, dynamic process. The sequential chart proposed includes several stages and steps corresponding to the main timings, which have been adapted from the strategic map method [12], to identify, organize, and describe strategies within the context of the water management model (Table 1).

Table 1. Sequential description of organizational analysis [12].

Stages	Steps	Description
Organizational identity	Mission	Why do we exist?
	Vision	What do we want to do?
	Values	What is important to us?
	Strategy	Our game plan
Organizational analysis	Strategic map	Translate the strategy
Organizational linkage	Balanced scorecard	To act, measure, and focus

At this stage, we proceeded to describe stakeholders involved in the proposed water organization, based on the present situation and envisaging the future one [25]. The required water management objectives have also been considered in order to understand the complexities and problems of managing the Mendoza River basin mainly in terms of making compatible the balance between supply and demand. At this stage:

- *Mission* is highlighted as the base of the water governance, the reason for its existence and its purpose, which is reflected in its activities.
- *Vision,* in turn, presents an image of the future, the course desired to be adopted and that enables knowing what is to be accomplished.
- *Values* allow knowing which aspects are important to water governance and constitute the reference framework for its image within the community. Values define the set of bases and principles that regulate water management of the organization and allow the building of the institutional philosophy [26].
- *Strategy* is the set of ordered actions that are developed in a dynamic way, according to the context and the capabilities available to implement them. It describes how a water organization intends to create values in the organization in relation to the services it offers, as well as to their implementation. The strategy covers various topics in a simultaneous and complementary manner, depending on their implementation timings, with operational processes usually being quicker than those that include the application of innovation processes. It also requires a specific link between the users and the values proposed to meet their needs [27].

A Strategic Map (SM) presents a causality structure enabling identification of components and interrelations of the organizational model's strategy with the aimed processes and results. It also allows assessing, measuring, and improving the most critical processes leading to their successful implementation. It makes it possible to conduct a strategic analysis, interpret the development stage of the strategy, and visualize the connection between tangible and intangible assets. Furthermore, an SM eases the assessment and selection of strategic options based on quantitative and qualitative criteria. The strategy's most critical factor is its efficient implementation, in order to ensure a sustained creation of value. In turn, this depends on the management of key internal processes, namely financial, operational, relations with costumers and innovation, and social and regulatory processes. Strategic maps, therefore, become visualization tools that facilitate the organizational description and drive the valuation process [13]. SM is thus a tool to measure organizational performance and to analyze the strategy used. It allows creating value from four different perspectives: a) the financial perspective, relative to the strategy for growth, profitability, and risk, viewed from the shareholder's perspective; b) the customer's perspective, referring to the strategy to create value and differentiation from the customer's viewpoint; c) the process perspective, relative to the strategic priorities of the different business processes that create satisfaction for clients and shareholders; and d) the learning and growth perspective, which refers to those intangible assets that are more important to develop strategies, such as human assets, information capital, and organizational culture.

The resulting SM makes use of all four perspectives described and is an important tool for strategy control through continuous monitoring. In addition, it allows explaining the strategy hypotheses in a coherent, integrated, and systemic way [12]. For the purpose of applying the SM method in this research, we adopted it by including an additional perspective related to water management, similar to that adopted in the Water Strategic Plan 2020 [28].

The Balanced Scorecard (BS) is a procedure corresponding to a management model of strategic initiatives. One of its main attributes is controlling financial variables jointly with those related to intangible assets. Using BS requires that objectives and associated indicators, both financial and nonfinancial, derive from the water organization's vision and strategy. For this reason, it is a method to align trends, business units, human resources, and technological means with the water organization's strategy [29]. The BS is generally proposed as an organized process involving different perspectives. Goals to reach are proposed for each perspective, which are causally related to one another. The model explaining these relationships is the above-mentioned Strategic Map, which describes the strategy hypothesis and raises the connection of the desired results of the strategy with the inducers and their linkage that will make them possible through relationships in different perspectives [13].

Social conflicts in the irrigated areas are manifested in: territorial transformations without planning and regulation, poor service to the irrigator, imbalances and inequities in water distribution, soil, water, and plant degradation, centralization in organizations, affecting territorial, economics, and productive competitiveness, with lack of profitability and investments in rural areas under irrigation and exodus of the peasant population to urban areas.

4. Modeling the Supply–Demand Water Balance

4.1. Water Balance Formulation

It is understood as the result of an adjusted model that contrasts water supply and demand at the level of the Administrative Unit of Management (AMU), considering agro-climatic conditions influencing irrigation demand and also nonagricultural uses [30], the following:

$$\mathrm{CWB} = \mathrm{GS} - \mathrm{GD} \tag{1}$$

where CWB represents the Mendoza River current water balance, GS is the mean Gross Supply from the river and contributing streams, and GD is the total Gross Demand per AMU, with the total GD per AMU defined as the sum of water demand per crop type:

$$\mathrm{GD} = \Sigma\,(\mathrm{RA} \times \mathrm{RC} \times \mathrm{ETc} \times \mathrm{Ef}) \tag{2}$$

where RA is the registered area having water rights per type of use in the AMU, RC is the reduction coefficient of water allocation depending upon the category of the granted water rights, ETc is crop evapotranspiration per type of land use, and Ef is the current global irrigation efficiency.

The AMUs were defined according to the available surface and groundwater sources of supply, as well as the existent channel network. Complementarily, we considered the catchment and channeling infrastructure, irrigation performance [31], edaphic conditions [32], and predominant land and water uses. The distribution system in the Mendoza River basin was analyzed, and existing WUOs were grouped into different AMUs according to their sources of water supply, the modality of operation of the system, and homogeneity criteria of management (Figure 3).

The WEAP model (Water Evaluation and Planning) [16] was adopted for calculating the supply–demand water balance. For the estimation of irrigation efficiency [4], two components were analyzed: the transport and distribution efficiencies through the canal system, and the irrigation application efficiencies relative to the farm fields [33]. Field efficiency studies were analyzed and compared with observed ones, particularly referring to the Mendoza River basin [34,35]. The following modeling parameters were considered: registered areas, reduction coefficients according to category of water rights, and average irrigation efficiencies (Table 2).

Table 2. Water rights to irrigation water use and efficiencies. Mendoza River basin.

Categories of Use	Permanent Water Rights	Temporary Water Rights	Public Town Irrigation	Urban Uses
Surface area (ha)	42,147	40,195	3,087	6,498
Allocation reduction coefficient	1	0.8	0.8	1
Farm application efficiency	51.4%			
Canal transport efficiency	81.8%			
Global efficiency	42.0%			

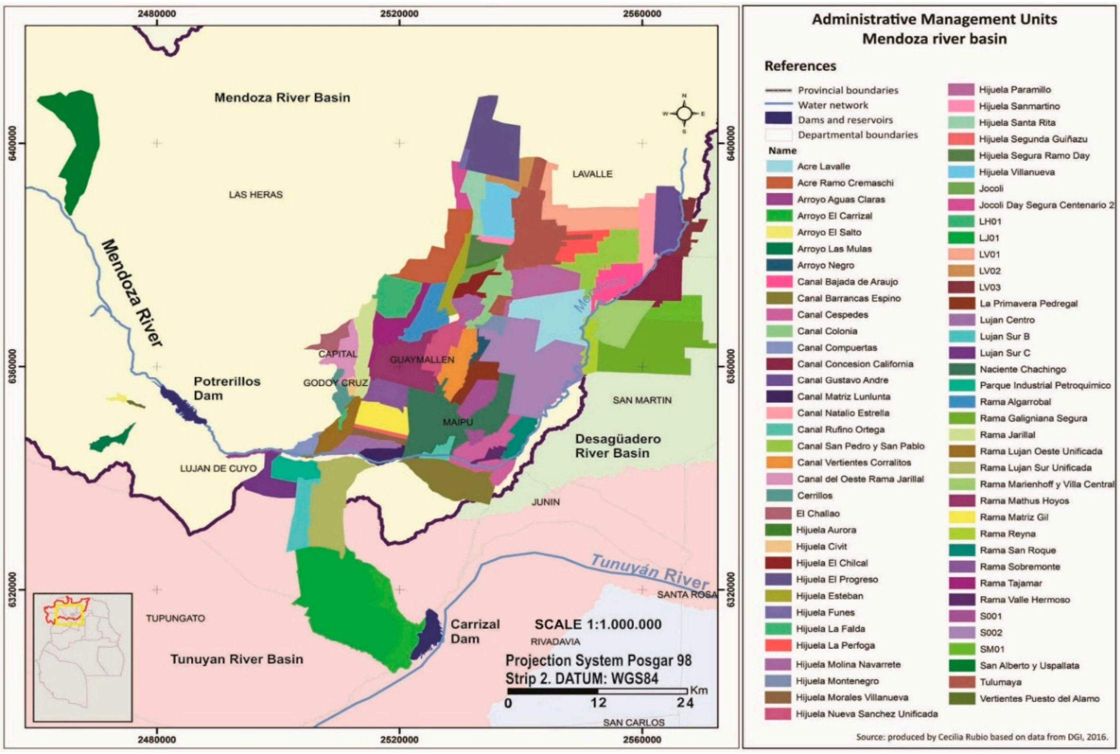

Figure 3. Administrative Management Units in the Mendoza River basin.

4.2. Water Supply

In assessing surface water resources, we considered the mean supply from river and streams, in accordance with the provisions of Provincial Laws 386 and 430, which mention it as a reference value for average flows [36]. The mean water supply from the Mendoza River was obtained from the study of water volumes recorded at the Guido gauging station, located upstream of the Potrerillos Reservoir before the exit to the fluvial valley in the pre-mountain massif (Figure 4).

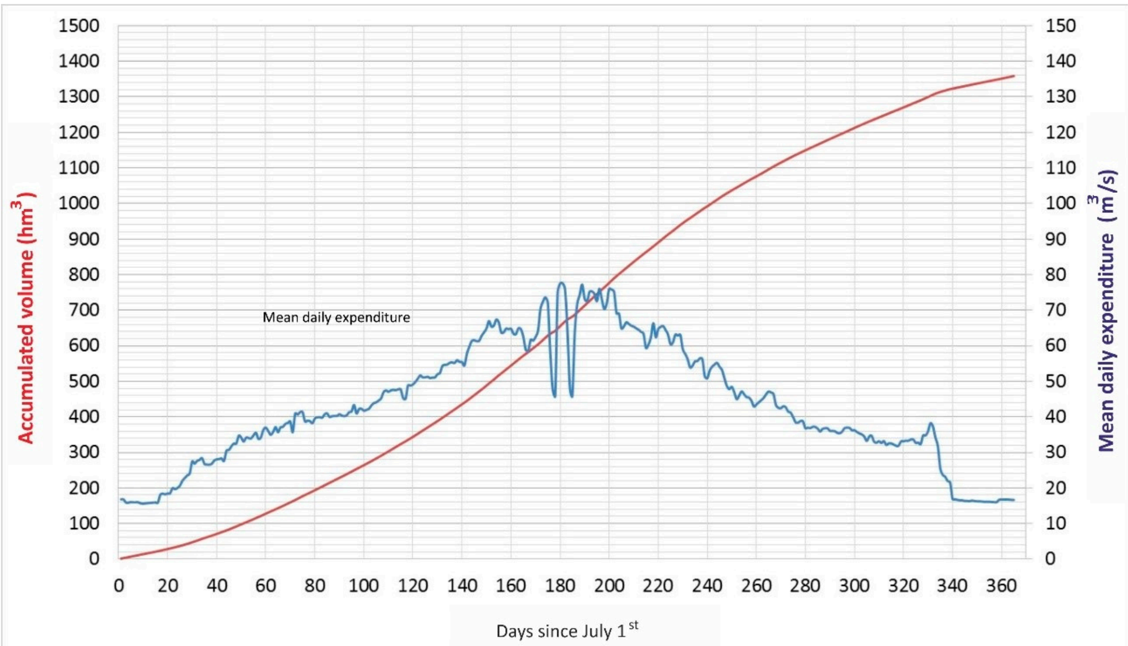

Figure 4. Mean daily water use curve and accumulated volume at Potrerillos Dam. (average values for 1 July 2006 to 30 June 2015).

The series of hydrologic years considered for modeling corresponds to the 2006–2015 period, which has been considered highly representative, and includes data on precipitation, operation, and spills. Yearly data of that period varies from rich to poor in terms of flow. In addition, for the same period, real-time nival and meteorological data from the Horcones and Toscas stations in the High Cordillera are made available to increase the integral hydrological knowledge of the basin. There is also information for this period about the operation of the Potrerillos Dam and Reservoir, the stabilization of management, and the calibration of hydro-mechanical equipment. Average historical volumes were computed from daily records, the average historical spills were assessed, and the average historical discharges were estimated with monthly frequencies for the Cipolletti Dam [5]. The operation of dams and reservoirs is dependent upon weather conditions, service provided by some branch canals, occurrence of rainfall, or compensatory measures that make the rules of operation be dynamic and varying from one cycle to other.

An analysis was made of the operations carried out in the modeling period. The recorded and modeled volumes discharged by the Potrerillos Dam were compared (Figure 5) and the quality of simulations performed was assessed with the Nash–Sutcliffe modeling efficiency indicator [37], resulting NSE = 0.82. This coefficient expresses the relative magnitude of the mean square error relative to the observed data variance. The maximum value is NSE = 1.0, which can only be achieved if there is a perfect match between all observed and simulated values. The closer the values of NSE are to 1.0, the better are the estimates of discharges. The obtained NSE value is quite high and therefore indicates that the simulation model provides confident results. Computations took into consideration the spill losses (Table 3).

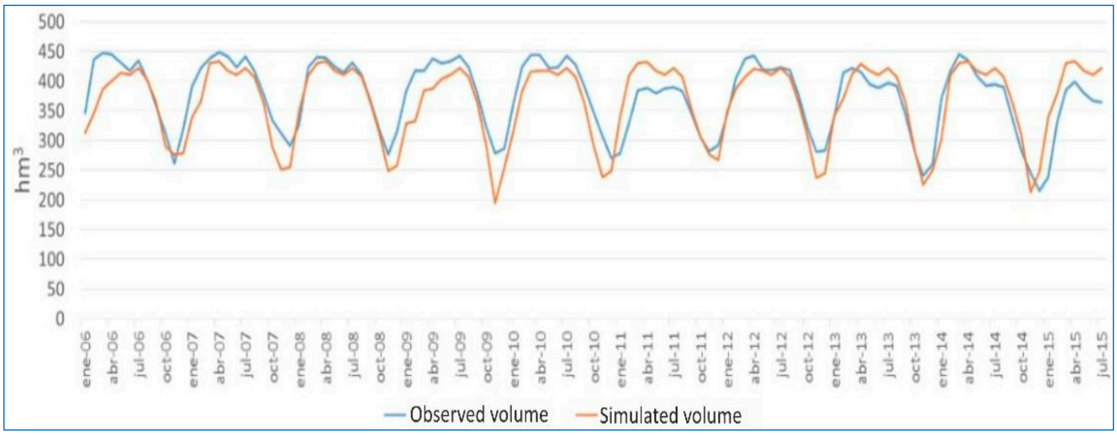

Figure 5. Validation of recorded and modeled volumes discharged by the Potrerillos Dam, 2006–2015.

Table 3. Averages spills at Potrerillos Dam, 2006–2015.

Spills (hm^3)												
Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Annual
65.0	94.6	124.9	161.4	182.8	163.3	128.4	96.7	73.6	70.8	57.8	41.4	1260.7

4.3. Water Demand

For estimation of water demand, various indicators of the water use performance were used [38]. Interactions between surface water and groundwater could not be omitted [3]. Demand and groundwater supply were estimated in a complementary manner for all AMUs considering groundwater use or a conjunctive use of surface and groundwater. In the case of conjunctive use, it was taken into account that groundwater pumping was only carried out in those fields equipped with wells and it was assumed that this pumped water was used to satisfy seasonal deficits due to scarce supply by the canal system [5].

Land use in agricultural areas has been characterized adopting representative crops for each AMU. Irrigation requirements were determined through the Kc-ETo approach that combines the reference evapotranspiration ETo with a crop coefficient characteristic of each crop [3,39]; net irrigation demands were computed by considering the local agricultural calendars for each type of crop as previously tested [40]. The referred WEAP software [16] accepts that the Kc-ETo approach is calculated externally by the user [41]. Thus, ETo was calculated using the FAO-PM method [39]; crop coefficients (Kc) and other parameters (e.g., crop phonological dates, soil characteristics) were obtained from literature [3,39,40] and adjusted to the AMU areas based upon existing field data [34]. For those computations, available climate data were used and spatially distributed using the method of Thiessen polygons [42]. These data allowed computing crop evapotranspiration and estimating effective precipitation, which directly contribute to meet crop demands [43], as well as other useful precipitation that may influence the efficiency of water use [44]. Spatial information was then obtained with a GIS tool. Data were used as input to the model built in the WEAP software [35]. It was therefore possible to characterize and map the main land uses (Figure 6) and water and irrigation requirements for the Mendoza River basin after aggregating results relative to all AMUs. Thus, the volumetric demand distribution was assessed for all selected series and AMUs. The procedure was replicated for diverse hydrologic years in the 2006–2015 period, with inclusion of demand variability depending on each year's weather conditions.

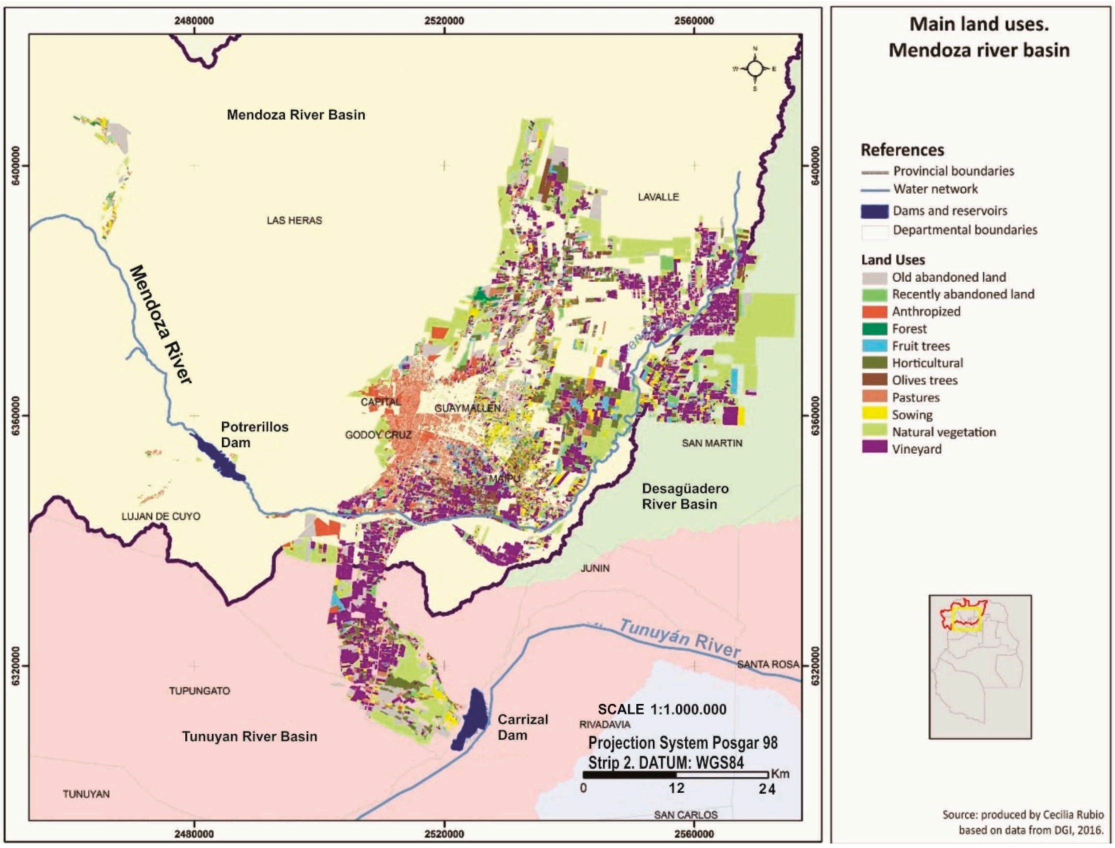

Figure 6. Main land uses. Mendoza River basin.

4.4. Supply–Demand Relationships

Supply and demand relationships have been determined for the current situation considering all granted water rights, the current irrigation efficiency, and the rules of operation of reservoirs, canals, and diversion dams. To this end, we considered two key indicators for achieving an appropriate supply–demand balance in the Mendoza River basin—*demand dissatisfaction* and *demand coverage* (percent of demand covered by the supply)—to estimate the percent guarantee of irrigation water [45], for which the reference value for the region is 81% [46]. Demand dissatisfaction corresponds to the difference between the water volume required to meet gross demand and the amount of supply available to satisfy such demand. This factor also allows determining the missing water volume (i.e., that cannot be covered by the available supply) [47]. There is also a link to the failure total, which is the summation of the monthly failures expressed in volume, understanding that a failure occurs when, in a certain month, supply does not suffice to meet the gross demand. The demand coverage corresponds to the percentage of gross demand effectively satisfied by the available supply, considering the monthly coverage for each AMU. It is computed as the difference to 100% of the ratio between failure and gross demand expressed in percentage. This value is lower than the global annual coverage because, although annual supply could have been enough to meet annual demand, when performing a monthly analysis, it became evident that the unevenness of such supply throughout the year results in months with deficit and others with surplus [22].

The global annual balance is calculated from the summing to the year of the volumes of supplies and demands. It indicates whether the annual supply–demand balance is deficient, excessive, or balanced. In turn, the global annual coverage is the percent value of the ratio between annual supply and annual gross demand. That coverage is limited to 100 percent to take into consideration that monthly surpluses or deficits are unevenly distributed throughout the year. Deficits for each AMU are computed monthly and expressed in hm3. The demand dissatisfaction is expressed in terms of ratios between water volume and area, the latter referring to where water is lacking, and is expressed in mm during the whole cycle. Another indicator is the percentage of gross demand met by the available supply, which corresponds to the inverse of the demand dissatisfaction when expressed in percentage [30].

5. Governance Organization and Forecasted Supply–Demand Balance

5.1. Governance Organizational Model

Mission, vision, values, and strategy are defined for the organizational water management model in an irrigated area of the Mendoza River basin with high social and environmental dynamics:

Mission: Building up an organizational model for local water management that responds to the socio-economic requirements of the land and water users of the irrigated area in the Mendoza River basin, particularly considering the users' participation through WUOs and AMUs.

Vision: Ensuring sustainable water use and productivity by achieving appropriate water demand management in a context of climate variability and territorial transformation in the Mendoza River basin.

Values: Responsibility with the community and the environment; effective participation of users; technical administrative efficiency in management; transparency in actions and communication; integrity and equity; commitment to local and territorial development.

Strategy: Achieving proper water administration performance in irrigated management units in the Mendoza River basin, using an autarchic, technically based organizational model that enables progressive implementation of training and innovation actions for sustainable use of water resources in the territory and that contributes to the local development process.

The proposed organizational model refers to an institution of public nature but not state-run, and with significant alliance with the private sector. Therefore, it must be taken into account that while for public sector organizations, it is relevant to analyze the system water use and management performance in order to achieve the defined mission with the highest level of success, for the private sector organizations, more importance is given to water and land productivity. Considering the above-mentioned aspects, objectives were grouped in agreement with key organizational dimensions, and to determine causal connections between objectives and perspectives, that is, cause–effect relationships, through building a strategic map of the organizational and governance model for the Mendoza River basin (Figure 7).

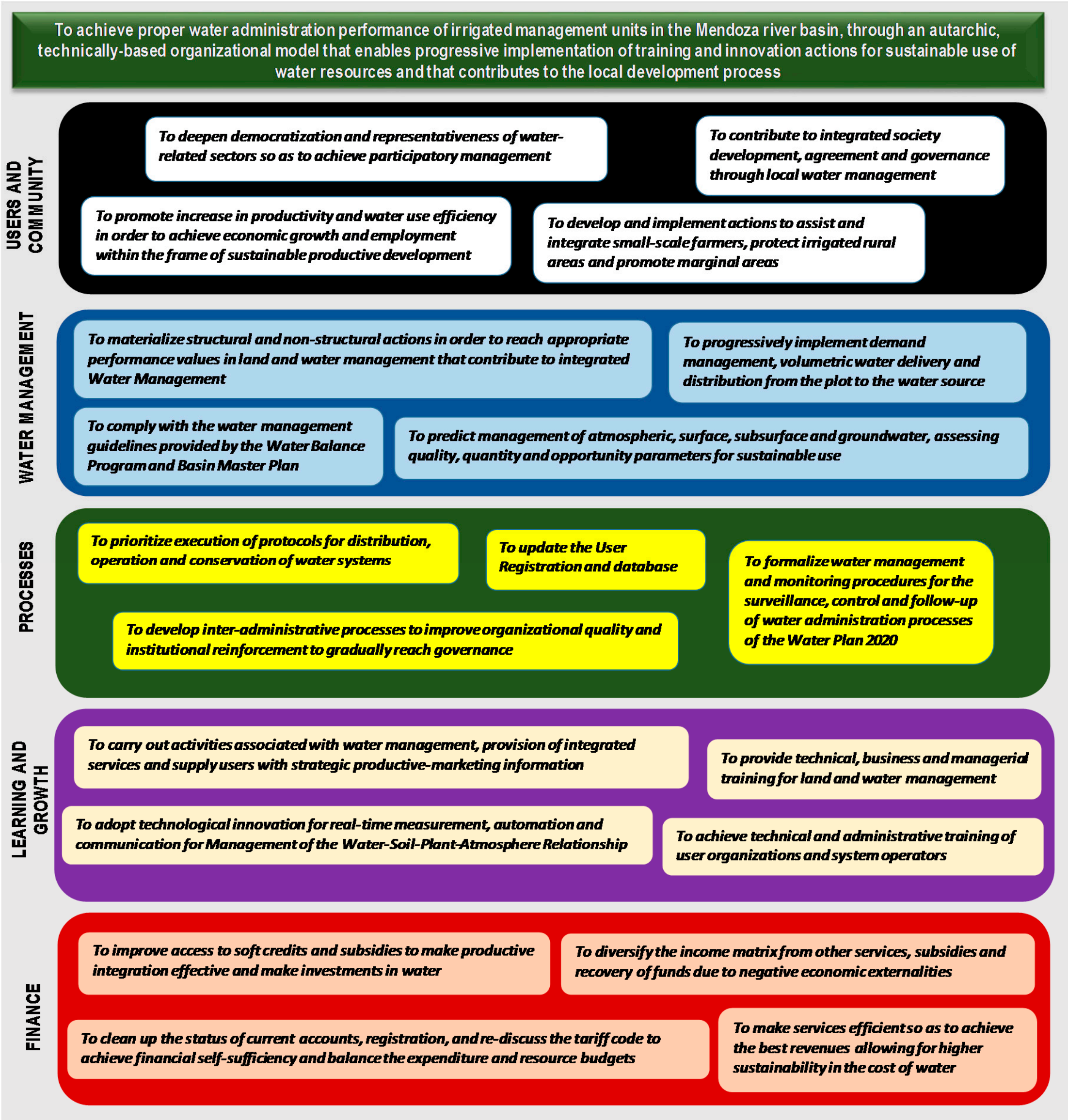

Figure 7. Summary of the strategic map of the organizational model for water governance in the irrigated area of the Mendoza River basin.

Among the most important aspects of the methodological adaptation of the Strategic Map (SM) and of a Balanced Scorecard (BS), the financial perspective was taken as the basis of the organizational model because financial and socio-economic variables have a great relevance in institutional functioning. The following indicators were therefore adopted: (i) financial self-sufficiency, ratio between the income resulting from water rights fees and the costs of operation, maintenance, and management of the water system [45]; (ii) performance of channel water allocation, ratio between effective and predicted recovery of water fees [45]; and (iii) monetary efficiency in water use, computed as the ratio of costs per volume of water allocated [48]. These indicators are used per every AMU. The learning and growth perspective is next in importance relating to the implementation of modern technical management, thus improving the capacity building of human resources and modernizing the hard- and software of the water system.

These water management issues definitely support technological innovation and are paramount to implement and develop both the learning process and the quality of the organizational processes. In addition, BS was methodically executed around different perspectives whose achievable aims were proposed. The organizational model that explains those relations in the strategic map helps describe the strategy's hypothesis aimed at fully achieving the water management goals.

5.2. Scenarios for Simulation

Forecasted supply–demand water balance alternatives were analyzed for the 2030 horizon. The *Demand Dissatisfaction* and *Demand Coverage* indicators were used. Three future scenarios (Table 4) were proposed in addition to the current one (Sc0):

- *Sc1 – when temporary water rights allow the use of up to 80% of the available water (i.e., RC = 0.80)*
- *Sc2 – when temporary water rights allow the use of up to 100% of the available water (i.e., RC = 1.0)*
- *Sc3 – when irrigation aims at satisfaction of the total registered area, including land where irrigation was previously abandoned*

The forecasts on the availability of surface water resources as influenced by climate change consider a reduction of snowfall of 20% by 2080, and an increase in air temperature of 4 °C for the next century [49]. For modeling purposes, an average reduction rate of snowfall close to 0.31% per year was adopted [50]. This decrease, together with the increase in temperature, induces a change in the basin hydrology that, on average and for the projected period of analysis, shall modify the flow regime and requires adaptability in the use of the water [51,52] because there would be higher flows in winter and lower ones in summer compared to present [53]. The induced variation of climate and hydrologic behavior in the context of global climate change [54,55] requires assessing water balance changes and related impacts on different categories of water rights in terms of area and/or water allocation. The cultivation of land presently abandoned but that could have water rights was not considered except for scenario Sc3.

Table 4. Main characteristics of scenarios used for supply–demand water balance modeling, Mendoza River basin.

Scenarios for the 2030 Horizon	Climate-Change-Affected Variables	Efficiency of Water Use	RC of Temporary Water Rights
Sc0 – Current water use and governance	Present condition	51%	0.80
Sc1 – Temporary water rights with RC = 80%	Reduced snowfall, higher temperature in lowlands, increased evapotranspiration	59%	0.80
Sc2 – Temporary water rights with RC = 100%		59%	1.00
Sc3 – Water service to the total registered area		59%	1.00

Factors commonly taken into account for developing and simulating all scenarios (Table 4) consist of: (i) an improved irrigation water management providing for a reasonable efficiency of water use of 59% without requiring structural changes in the canal system; (ii) a decrease in mountain snowfall that would lead to the variation of the river flow regime, thus to adaptation changes in water supply; (iii) an increase in temperature in the lowlands that likely will cause variable increases in evapotranspiration and demand for water, depending on the type of water use; (iv) variation in land use, namely referring to the distribution of areas cropped and urbanized; and (v) changes in management and operation of the basin water system, mainly relative to the governance issues, improvement of the AMUs, and more effective participation of users through the respective WUOs.

5.3. Forecasts for Supply–Demand Water Balance for the 2030 Horizon

The previously defined gross demand, the supply and failure total, the percent coverage of demand by supply (including total failures), the global supply–demand balance, and global annual coverage of demand by supply were estimated using WEAP for both agricultural and other consumptive uses. Results relative to the considered scenarios are presented in Table 5.

Table 5. Comparing results for supply–demand water balance scenarios for the 2030 horizon, Mendoza River basin.

Scenarios for the 2030 Horizon	Registered Cropped Area (ha)	Gross Demand (hm^3)	Supply Total (hm^3)	Failure Total (hm^3)	Demand Coverage (%)	Global Annual Balance (hm^3)	Global Annual Coverage (%)
Sc0 – Current water use and governance	54,720	955.49	1131.05	−34.26	96.4%	175.57	100%
Sc1 – Intermittent water rights, RC = 0.8	54,720	793.09	1040.47	−4.07	99.5%	247.38	100%
Sc2 – Intermittent water rights, RC = 1.0	59,342	866.30	1042.79	−5.58	99.4%	176.49	100%
Sc3 – Service to the total registered area	76,534	1170.44	1049.65	−170.74	85.4%	−120.79	86%

The current balance (Sc0) does not include the abandoned old lands, but does take into account the factors of the current climate and the existing efficiency in the farm, which reaches an average value of 51.4%. Analyzing the indicators produced when modeling with scenario Sc1 (temporary water rights and RC = 0.8), it was observed that indicators are generally better than those obtained for the current condition (Table 5) despite global change-influenced climate and hydrologic variables for the 2030 horizon, resulting in increased demand and more varied water supply. That improvement is likely due to higher farm application efficiency, 59% vs 51%, and to an optimized operation of reservoirs and diversion dams, which are expected to contribute to decreasing failures and improving the water supply distribution service, thus resulting in an increased guarantee of irrigation water availability.

For Sc2 (temporary water rights and RC = 1.0), there is a larger registered cropped area due to transformation of temporary into permanent water rights. An increase in annual gross demand of 73.21 hm^3 occurs and there is a negligible increase of 1.51 hm^3 in the sum of failures, while the base water supply remains the same. An improved supply is considered due to improvements in water distribution and global efficiency, which are expected to keep failures, demand coverage, and global annual coverage at levels similar to Sc1. However, the global annual balance diminishes. Notwithstanding, analyzed in general, this difference continues to be positive for average years.

The modality Sc3 is for a scenario where the whole of the granted area in the basin is predicted to have irrigation, thus including all abandoned lands, recently or not. The sum of failures reaches then a high value of 170.74 hm^3, particularly important due to high demand when river runoff is low. Demand coverage falls to 85% while the gross demand increases about 215 hm^3 and the global annual coverage reaches 86%. But even so, these values are above the regional reference value of the irrigation water guarantee percentage. Thus, scenario Sc3 requires adopting additional measures not considered in this study.

6. Conclusive Remarks

A strategic formulation of the organizational model was defined after performing a strategic analysis of the organization. Designing the strategic map of the organization from the perspective of users and the community and relating to new perspectives on water management, processes, learning and knowledge, and finance responded well to objectives. Moreover, in the proposed organizational and governance model, the effective participation of users was considered as the main basis for formulating institutional cross-sectoral (horizontal/integral) policies. That participation is aimed at concrete decision-making by all stakeholders involved in every circumstance concerning water management. The result is that the designed SM for the Mendoza River basin is aimed at supporting sustainable productive development and satisfaction of socio-economic requirements through an appropriate supply–demand management and adopting volumetric water delivery to users. The Administrative Units of Management (AMUs) were adopted to manage water at local level, and the areas of influence of the WUOs were reformulated accordingly.

The evaluation of the water resources of the Mendoza River basin was performed and an analysis was made of the operations carried out in the modeling period of 2006–2015. The recorded and modeled volumes at the Potrerillos dam were compared. A high value of 0.82 for the Nash–Sutcliffe modelling efficiency indicator of goodness of fit was obtained, which allowed considering that the available supply was confidently assessed. The demand was estimated on basis of previous studies and used the updated methodology of FAO56 guidelines. The balance supply-demand was computed with model WEAP. For the modeling period of 2006–2015 three scenarios were tested and compared with the base one referring to present conditions. It was observed that more requiring scenarios than present were evaluated positively but not a scenario where irrigated areas would increase much to include presently abandoned ones. Positive results were obtained due to the new organization and governance model, which assumed decentralized water management through the AMUs, users' participation with the Water User Organizations (WUOs), and increased global water efficiency due to improved water management and canal transport and deliveries through adopting innovative approaches related to hard- and software, as well as capacity building.

Author Contributions: M.S.-S. made the characterization of the study basin and the coordination in modeling the water balance and J.F.-D. formulated the model of water governance. Both authors wrote the article.

Acknowledgments: Luis S. Pereira, University of Lisbon for advising on irrigation modernization and management and revising the last version of the article, Joan Mateu and Joan Romero, Universitat de València, and Antonio Rico Amorós, Universidad de Alicante, for contribution of theoretical framework. José Álvarez; Carlos Sánchez; Juan Pina, and Bernardo Herrera for their strategic contributions of the Water 2020 Plan in the water management of Mendoza that were considered in the article. Jorge Chambouleyron, Cecilia Rubio, Elena Abraham, Juan Satlari, Guillermo Cuneo, Gonzalo Muñiz, and Nora Mustoni for the collaboration and scientific review of the materials and methods used; Elma Montaña, Christopher Scott, and Facundo Martin for the conceptual vision of the science and policy dialogue considered in the formulation of the model.

Conflicts of Interest: The authors declare to have no conflicts of interest.

References

1. Salomón, M.; Álvarez, J. *Preservación y Promoción de Zonas Irrigadas en el Marco del Plan Agua 2020 y Plan de Ordenamiento Territorial de Mendoza. I Jornadas Nacionales de Investigación en Ciencias Sociales. Cambio Climático y Desarrollo Sostenible en las Ciencias Sociales*; Facultad de Ciencias Políticas, Universidad Nacional de Cuyo: Mendoza, Argentina, 2016.
2. Salomón, M.; Rosell, M.; Thomé, R.; Albrieu, H.; López, J.; Ruiz Freites, S.; Yapura, J. *El Aporte de la GIRH a Través de las Organizaciones de Usuarios en el Ordenamiento Territorial y Desarrollo Estratégico de Mendoza. XXI Congreso Nacional del Agua*; CONAGUA: Resistencia, Chaco, 2011; Chapter 2; pp. 42–58.
3. Pereira, L.S.; de Juan, J.A.; Picornell, M.A.; Tarjuelo, J.M. *El Riego y sus Tecnologías*; Centro Regional de Estudios del Agua, Universidad de Castilla-La Mancha: Albacete, Spain, 2010; 296p, Available online: http://crea.uclm.es/crea2/sp/index.php (accessed on 16 September 2018).
4. Chambouleyron, J. *Riego y Drenaje. Técnicas Para el Desarrollo de una Agricultura Regadía Sustentable Mendoza*; Editorial Universidad Nacional de Cuyo, EDIUNC: Mendoza, Argentina, 2005; 1026p.
5. Departamento General de Irrigación (DGI). *Datos y estadísticas Cuencas de Mendoza. Dirección de Gestión Hídrica*; Dirección de Recaudación y Finanzas: Mendoza, Argentina, 2016.
6. Salomón, M.; Ruiz Freites, S. La Descentralización en la Administración del Agua. In Proceedings of the XX Congreso Nacional del Agua, Mendoza, Argentina, 9–13 May 2005.
7. Salomón, M. El desafío del riego frente a la escasez hídrica en Mendoza. In Proceedings of the VI Jornadas de Riego y Fertirriego, Luján de Cuyo, Mendoza, Argentina, 7–9 November 2012; Facultad de Ciencias Agrarias, Universidad Nacional de Cuyo: Mendoza, Argentina, 2012.

8. Domínguez, J. *Hacia una Buena Gobernanza Para la Gestión Integrada de los Recursos Hídricos. VI Foro Mundial del Agua. Documento Temático de las Américas: Los Mensajes Clave de las Américas. Los Marcos Legales e Institucionales del agua dan Certidumbre a los Agentes Sociales y Favorecen el Financiamiento para el Sector Hídrico, Ordenamiento Territorial y Desarrollo Estratégico de la Cuenca del Rio Mendoza, Argentina. Adopción de la Ley de Ordenamiento Territorial, Integrando los Principios de la GIRH World Water Fórum*; Colegio de México: Mexico City, Mexico, 2011; Volume 1, pp. 22–23.
9. Farinós, J. *Gobernanza Territorial Para el Desarrollo Sostenible: Estado de la Cuestión y Agenda*; Boletín de la A.G.E. N° 46; Asociación de Geógrafos Españoles: Madrid, Spain, 2008; Volume 46, pp. 11–32.
10. Pedregal Mateos, B.; Laconi, C.; Mancilla García, M.; Orozco Frutos, G.; Figueroa, A.; Cabello Villarejo, V.; Moral Ituarte, L. Collaborative mapping of wáter conflicts in Andalusia, Spain. In Proceedings of the Open Science Conference Pecs II, Oaxaca, Mexico, 7–10 November 2017.
11. Romero, J.; Farinós, J.; Presentación en Romero, J.; Farinós, J. (Eds.) *Gobernanza Territorial en España. Claroscuros de un Proceso a Partir del Estudio de Casos*; Publicaciones de la Universidad de Valencia/Instituto Interuniversitario de Desarrollo Local, Colección Desarrollo Territorial: Valencia, Spain, 2006; pp. 15–19.
12. Kaplan, R.; Norton, D. *Mapas Estratégicos. Convirtiendo los Activos Intangibles en Resultados Tangibles*; Harvard Business Review Press: Barcelona, Spain, 2004; ISBN 9781591391340.
13. Bustos, G. *Mapa de Objetivos Organizacionales: Una Generalización del Mapa Estratégico*; Pontificia Universidad Católica de Valparaíso: Valparaíso, Chile, 1997.
14. Abraham, E.; Salomón, M.; Rubio, C.; Soria, D. *Aportes Metodológicos para Evaluación Hidrológica de Cuencas Andinas. Estudio Cuenca Río Mendoza*; Revista Zonas Áridas; Centro de Investigaciones de Zonas Áridas, Universidad Nacional Agraria La Molina: Lima, Perú, 2010; Chapter 1; pp. 9–33.
15. FAO-PNUD. *Planes Directores de Ordenamiento de los Recursos Hídricos de la Provincia de Mendoza. Informe Principal Plan Cuenca Río Mendoza*; Proyecto PNUD/FAO/ARG/00/008; FAO-PNUD: Mendoza, Argentina, 2004.
16. Stockholm Environment Institute (SEI). WEAP (Water Evaluation and Planning). Available online: http://www.weap21.org/ (accessed on 8 February 2017).
17. Morábito, J.; Hernández, J.; Martinis, N. *Fornero, L. Modelación Hidrológica de la Cuenca Norte de Mendoza*; IT N° 146; Centro Regional Andino (CRA): Mendoza, Argentina, 2012.
18. Piccone, L.; Salomón, M. *El manejo del Agua de Riego en la Provincia de Mendoza. Ejemplo de usos y Aprovechamiento de Aguas en el Gran Mendoza*; Mendoza en el 2000; Facultad de Ciencias Agrarias, Universidad Nacional de Cuyo, Centro Coordinador de Ediciones Académicas: Mendoza, Argentina, 1994; Chapter 12; pp. 97–103.
19. GWP. *Manual para la Gestión Integrada de Recursos Hídricos en Cuencas". Network of Basin Organizations. Global Water Partnership International*, 1st ed.; Empresa Gráfica Mosca: Paris, Republiqué Française, 2009; 111p.
20. Estrada, F.; Luján García, L. *Criterios de Garantía en la Planificación de Regadíos*; CEDEX (Centro de Estudios y Experimentación de Obras Públicas): Madrid, Spain, 1993.
21. Pereira, L. Necessidades de agua e programação da rega: Modelação, avanços e tendências. In *Modernización de Riegos y Uso de Tecnologías de Información (Taller Internacional, La Paz, Bolivia, September 2007)*; Ruz, E., Pereira, L.S., Eds.; CYTED and PROCISUR/IICA: Montevideo, Uruguay, 2008; pp. 14–16.
22. Balairón Pérez, L. *Gestión de Recursos Hídricos*; Politext: Barcelona, Spain, 2002; Volume 89.
23. INDEC. *Censo 2010. Año del Bicentenario*; Instituto Nacional de Estadísticas y Censos (INDEC): Buenos Aires, Argentina, 2010.
24. Salomón, M.; Abraham, E.; Sánchez, C.; Rosell, M.; Thomé, R.; López, J.; Albrieu, H. Análisis de los Impactos Ambientales Generados por las Presas Sobre los Sistemas de Riego. In *Tecnologías para o uso Sustentável da Água em Regadió*; Cuenca Río Mendoza, P.L., Brea Victoria, F., Paredes, P., García, M., Palacios, E., Torrecillas, A., Eds.; Edições Colibri: Lisboa, Portugal, 2008; Chapter 5.7; pp. 122–128.
25. Godet, M. *Prospectiva Estratégica: Problemas y Métodos*, 2nd ed.; Cuaderno N° 20; Ediciones: Donostia-San Sebastián, Spain, 2007.
26. Matus, C. *Política, Planificación y Gobierno. Organización Panamericana de la Salud*; Organización Mundial de la Salud, Fundación Altadir, ILPES: Buenos Aires, Argentina, 1987; pp. 242–359.
27. Miklos, T.; Arroyo, M. *Prospectiva y Escenarios para el Cambio Social*; Serie Working Papers; FCPS-UNAM: Mexico City, Mexico, 2008.

28. Departamento General de Irrigación (DGI). Plan Agua 2020. Mendoza. 2014. Available online: http://www.agua.gob.ar/2020/sobre-el-plan (accessed on 20 January 2017).
29. Martínez Pedros, M.; Milla Gutiérrez, A. *La Elaboración del Plan Estratégico a Través del Cuadro de Mando Integral*; Ediciones Díaz de Santos SA: Madrid, Spain, 2005.
30. Álvarez, J.; Pina, J.; Sánchez, C.; Salomón, M. *Hydrological Balance Implementation in Mendoza's Province. Decision support and modeling tool for integrated management of water resources*, 3rd ed.; Inter-Regional Conference on Land and Water Challenges: Tools for developing, Colonia, Uruguay, 27–30 September 2015; Available online: http://www.ainfo.inia.uy/digital/bitstream/item/5026/1/Agrociencia-Congreso-CIGR2015.pdf (accessed on 21 December 2016).
31. USBR. *Bureau of Reclamation Manual. Volume V. Irrigated Land Use, Part. 2 Land Classification*; US Dept. Interior: Washington, DC, USA, 1953.
32. Vallone, R.; Maffei, J.; Olmedo, G.; Morábito, J.; Mastrantonio, L.; Lipinski, V.; Filippini, M.F. *Mapa de Aptitud de Suelos con Fines de Riego y de Riesgo de Contaminación Edáfica de los Oasis Irrigados de la Provincia de Mendoza*; Informe Técnico Final, Componente de Calidad de Agua y Suelo. Programa de Riego y Drenaje; Departamento General de Irrigación-Programa de Servicios Agrícolas Provinciales–Organización de Estados Iberoamericanos: Mendoza, Argentina, 2007.
33. ASAE—American Society of Agricultural Engineering. *Evaluation of Irrigations Furrows*; EP419.1.USA; ASAE: Washington, DC, USA, 2000; pp. 893–898.
34. Morábito, J. *Desempeño del Riego por Superficie en el Área de Riego del Río Mendoza: Eficiencia Actual y Potencial: Parámetros de Riego y Recomendaciones para un Mejor Aprovechamiento Agrícola en un Marco Sustentable*; Universidad Nacional de Cuyo, Facultad de Ciencias Agrarias: Mendoza, Argentina, 2003; 97p.
35. Satlari, G.; Cúneo, G.; Mustoni, N. *El Balance Hídrico como Herramienta de Planificación; Congreso Nacional del Agua*; Argentina CONAGUA: Paraná, Argentina, 2015.
36. Ruiz Freites, S. *Legislación y administración de Aguas en Mendoza, Capítulo XI Legislación y Administración del Agua en Mendoza, en Mathus Escorihuela, M. (Dir.). Derecho y Administración de Aguas*, 1st ed.; Zeta Editores: Mendoza, Argentina, 2007; pp. 409–465.
37. Nash, J.E.; Sutcliffe, J.V. River flow forecasting through conceptual models: Part 1. A discussion of principles. *J. Hydrol.* **1970**, *10*, 282–290. [CrossRef]
38. Pereira, L.S.; Cordery, I.; Iacovides, I. Improved indicators of water use performance and productivity for sustainable water conservation and saving. *Agric. Water Manag.* **2012**, *108*, 39–51. [CrossRef]
39. Allen, R.; Pereira, L.; Raes, D.; Smith, M. *Evapotranspiración del Cultivo. Guías Para la Determinación de los Requerimientos de Agua de los Cultivos*; Estudio para Riego y Drenaje FAO: Rome, Italy, 2006; Nro. 56; 298p.
40. Salomón, M.A.; Sánchez, C.M.; Pereira, L.S. Estimación del balance hídrico mediante aplicación del modelo ISAREG en el Canal Segundo Vistalba, Lujan de Cuyo, Mendoza (Argentina). In *Modernización de Riegos y Uso de Tecnologías de Información*; Ruz, E., Pereira, L.S., Eds.; CYTED and PROCISUR/IICA: Montevideo, Uruguay, 2008; pp. 115–117.
41. Satlari, G.; Cúneo, G. *La Asignación del agua, a Definir en el Balance Hídrico, Requiere una Mejor Eficiencia de Riego*; CONAGUA 5.230; Congreso Nacional del Agua: Paraná, Argentina, 2015.
42. Chow, V.; Maidment, D.; Mays, L. *Hidrología Aplicada*; Editorial Mc Graw-Hill: Bogotá, Colombia, 1994; 583p.
43. González Loyarte, M.; Menenti, M.; Diblasi, A. Mapa bioclimático para las Travesías de Mendoza (Argentina) basado en la fenología foliar. *Revista FCA UNCuyo* **2009**, *41*, 105–122.
44. Casas, R.; Albarracín, C. (Eds.) *El Deterioro de los Suelos y del Ambiente en la Argentina*; Editado por Fundación para la Educación, la Ciencia y la Cultura Buenos Aires (FECIC-PROSA): Buenos Aires, Argentina, 2015; Tomo I; 604p, Tomo II; 452p, ISBN 978-950-9149-40-3.
45. Bos, G.; Chambouleyron, J. *Parámetros de desempeño de la agricultura de riego de Mendoza, Argentina*; Instituto Internacional del Manejo del Agua: Mexico City, Mexico, 1999.
46. De Mendoza, G. *Aprovechamiento Integral del Río Mendoza. Proyecto Potrerillos. Manifestación General de Impacto Ambiental (Ley N° 5961)*; Ministerio de Ambiente y Obras Públicas, Subsecretaría de Medio Ambiente (MAyOP): Mendoza, Argentina, 1998.
47. Sánchez, C.; Salomón, M.; Pereira, L. Evaluación del desempeño de los sistemas de distribución de riego tradicionales mediante uso del modelo ISAREG en Mendoza (Argentina). In *Tecnologías Para o uso Sustentável da Água em Regadió*; Pereira, L., Brea Victoria, F., Paredes, P., García, M., Palacios, E., Torrecillas, A., Eds.; Edições Colibri: Lisboa, Portugal, 2008; Chapter 5.5; pp. 114–117.

48. Sánchez Cohen, M.; García Vargas, Y. *Índices de Desempeño de Los Distritos de Riego del Noroeste de México*; INIFAP CENID-RASPA Universidad Autónoma Chapingo, Unidad Regional Universitaria de Zonas Áridas: Texcoco, México, 2004; 4p.
49. Martin, F.; Montaña, E.; Mussetta, P.; Salomón, M.; Scott, C. *Science-Policy Dialogue and Adaptation: Fascing short, Medioum and Long Term Scenarios in Mendoza (Argentina)*; Third Interational Cimate Change; I: 147. Ed.; Governo de Brasil, PROVIA-INPE, Fortaleza: Ceará, Brasil, 2014.
50. IPCC. *Fourth Assessment Report: Climate Change 2007 (AR4). Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2007.
51. Organización Meteorológica Mundial. *Guía de Prácticas Hidrológicas. Adquisición y Proceso de Datos, Análisis, Predicción y Otras Aplicaciones*; OMM Nº 168: Buenos Aires, Argentina, 1994.
52. Salomón, M. Water security and climate adaptation: Bridging science and policy. The case of the Mendoza River Basin. In Proceedings of the XVI World Water Congress, 29 May–3 June 2017; International Water Resources Association (IWRA): Cancún, Mexico, 2017.
53. Bonisegna, J. *Impacto del Cambio Climático en los Oasis del Oeste Argentino. Revista Ciencia e Investigación;* Tomo 64 n°1: Buenos Aires, Argentina, 2014; pp. 45–58.
54. Villalba, R.; Bonisegna, J.; Masiokas, M.; Cara, L.; Salomón, M.; Pozzoli, J. *Cambio Climático y Recursos Hídricos. El Caso de las Tierras Secas del Oeste Argentino*; Revista Ciencia Hoy; Editoriales Asociación Civil Ciencia Hoy AAPC: Buenos Aires, Argentina, May–June 2016.
55. Villalba, R.; Bonisegna, J. *Cambios Climáticos Regionales en el Contexto del Calentamiento Global*; Informe Ambiental 2009; Secretaría de Ambiente, Gobierno de Mendoza: Mendoza, Argentina; Available online: https://es.scribd.com/document/323170636/Informe-Ambiental-2009 (accessed on 17 October 2016).