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Water: Drought, Crisis and Governance in Australia and Brazil

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Abstract: Despite huge differences in population, household income and development levels, Australia and Brazil have some temporal convergences in their water governance systems. Over the last 20 years, both countries have significantly reformed their water policies and practices by introducing a legal foundation for more integrated and participatory catchment/basin management based on the best information available. A critical test of any water reform is how effective it is in meeting the challenges of extreme and unpredictable conditions of drought and floods, which are expected to increase under climate changes scenarios. This paper compared the contemporary water governance frameworks of Australia and Brazil in relation to three elements of Integrated Water Resources Management (IWRM): integration, participation, and information/knowledge. We focused on insights from Brazil's recent drought and Australia's fluctuating water crises to derive lessons and recommendations for future changes. Among the main recommendations, we stress the need for both systems to improve effective participation and to embrace a more comprehensive approach to cope with water scarcity in future scenarios. Furthermore, water related decisions should be based on a transparent and well informed process, and take into account the lessons from similar situations worldwide in order to avoid unnecessary or ineffective measures. As demonstrated in the Australian case during the Millennium Drought, the most effective initiatives were those involving government, the private sector and society to achieve a more sustainable consumption pattern in all sectors. There is much to learn from the Brazilian and Australia experiences in water reforms and crises, but it is imperative to understand the social, economic and environmental context within which these took place. Continuing to develop the capacity and willingness of researchers and policy makers to work together can make an important contribution towards meeting the growing and spreading challenges in water resource management around the world.

Keywords: water governance; drought; water crisis; Australia; Brazil; climate change

1. Introduction

Following increasing environmental degradation, associated with mass consumption by the global society, the Earth's water resources face a serious threat. Postel's [1] diagnosis that the death of the Aral sea was linked to the over exploitation of its water sources, and strains on the Colorado river were from massive human intervention along its entire length, reinforced the need for the numerous

actions that have been taken worldwide towards better water management. However, the gap between the need for action and real outcomes has grown at an even higher rate. Mapping of water stressed areas in 2000 indicated that 45% of the world population faced water supply constraints [2]. In a recent review 10 years later, the gap had grown to almost 80% of the world population being exposed to high levels of threat to water security [3].

In a seminal paper, Vorosmarty and Sahagian [4] discuss the human influence on the hydrological cycle, embracing three aspects: the magnitude of hydraulic engineering intervention on natural water streams, the impacts, and the uncertainty associated with water availability forecasts. The authors pointed out a possible scenario of sea level rise coupled with a significant decrease in the stock of continental waters—which is directly related to the water availability for human needs. They indicated that the lack of analysis of real impacts associated with water related works, like dams, water diversions and water withdrawals, amongst others, increases the risk associated with such projects and drives watercourses towards unsustainability. Further, Pearce [5] also shows how water resources are following a trajectory of depletion, tracking several water constraint cases worldwide, illustrating, in a different manner, Vorosmarty's predictions.

Thus, water is becoming physically, economically and socially scarce in several places where it was abundant years ago, and some places are experiencing water shortages at an increasing rate. Most of the global climate change models predict reduced precipitation, including over the most populated areas of the two countries which are the focus of this paper, Australia and Brazil. These two largest countries and economies in the Southern Hemisphere would also be the most affected by reduced precipitation scenarios. Actually, both countries have experienced severe droughts recently, which have challenged their water management schemes.

Around 10 years ago, Australia faced its most severe drought, the Millennium Drought [6,7], which affected, directly and indirectly, the entire country. According to a recent report, in Australia, despite the slightly increased rainfall since 1900 overall, rates have declined since 1970 in the southwest, with a reduced winter and autumn rainfall. Furthermore, while Australian temperatures are projected to increase, average rainfall in the most populated areas of southern Australia is projected to decrease [8].

Similarly, the latest Brazilian climate projections [9] indicate a significant decrease in rainfall in the southeast, central and northeast region, coupled by a temperature increase. The rainfall decrease could reach 20% below the historical average by 2040, and to an impressive 40% of the average by 2100. In the last two years, Brazil has faced its most severe drought since the first historical record.

These trends should logically drive nations to a more resilient approach to water use and management as espoused by the concept of Integrated Water Resources Management (IWRM). IWRM principles were first well formulated in the International Conference on Water and the Environment (ICWE) in 1992 [10]. The Global Water Partnership (GWP) defines it as "a process which promotes the coordinated 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" ([11], p. 1). Core concepts include: management of the whole resource on a catchment basis; integration of domestic, agricultural, industrial and environmental needs; participatory processes with representation of water users and including recognition of the role of women in water management; and balancing Economic efficiency, Ecosystem sustainability and social Equity (the three E's). Two of the pillars of IWRM are an enabling environment of suitable polices, strategies and legislation for sustainable water management and an appropriate institutional framework [11]. As a result, governance warrants attention.

While there are different institutional and economic capacities to address challenges, both Australia and Brazil have achieved significant milestones in water reforms over the past twenty years. These large countries, both with similar layers of government (federal, state, and municipality), took different institutional approaches to dealing with problems of a similar nature: water scarcity, droughts, floods and climate change. In this article we first compare legal and institutional aspects

of the water governance framework in Australia and Brazil. We then compare and assess three core principles of IWRM that are of particular importance as we move forward: integration, community participation and decentralized decision-making, and information transparency. We review the challenges of coping with a changing climate, with a focus on droughts as an example of a climate extreme and note the contradictory role of adaptive management in this context. We found that while good progress has been made, both countries have more work to do to achieve sustainable water resource management and offer the most relevant lessons to help address future challenges. Such lessons may be useful to other jurisdictions facing similar issues with water use and management.

2. Water Governance in Australia and Brazil: Main Legal and Institutional Aspects

Australia and Brazil have made significant changes in their water management legal and institutional framework in the last 20 years. The drivers for changes were different in each country: while severe drought was an impetus for changes in Australia, in Brazil new socio-political arrangements in the early 1990s were a major driver for revising the water management system. These are both federal systems with various levels and layers of decision-making authority.

The most important steps in the water management framework reform in Australia and Brazil are shown in a timeline in Figure 1.

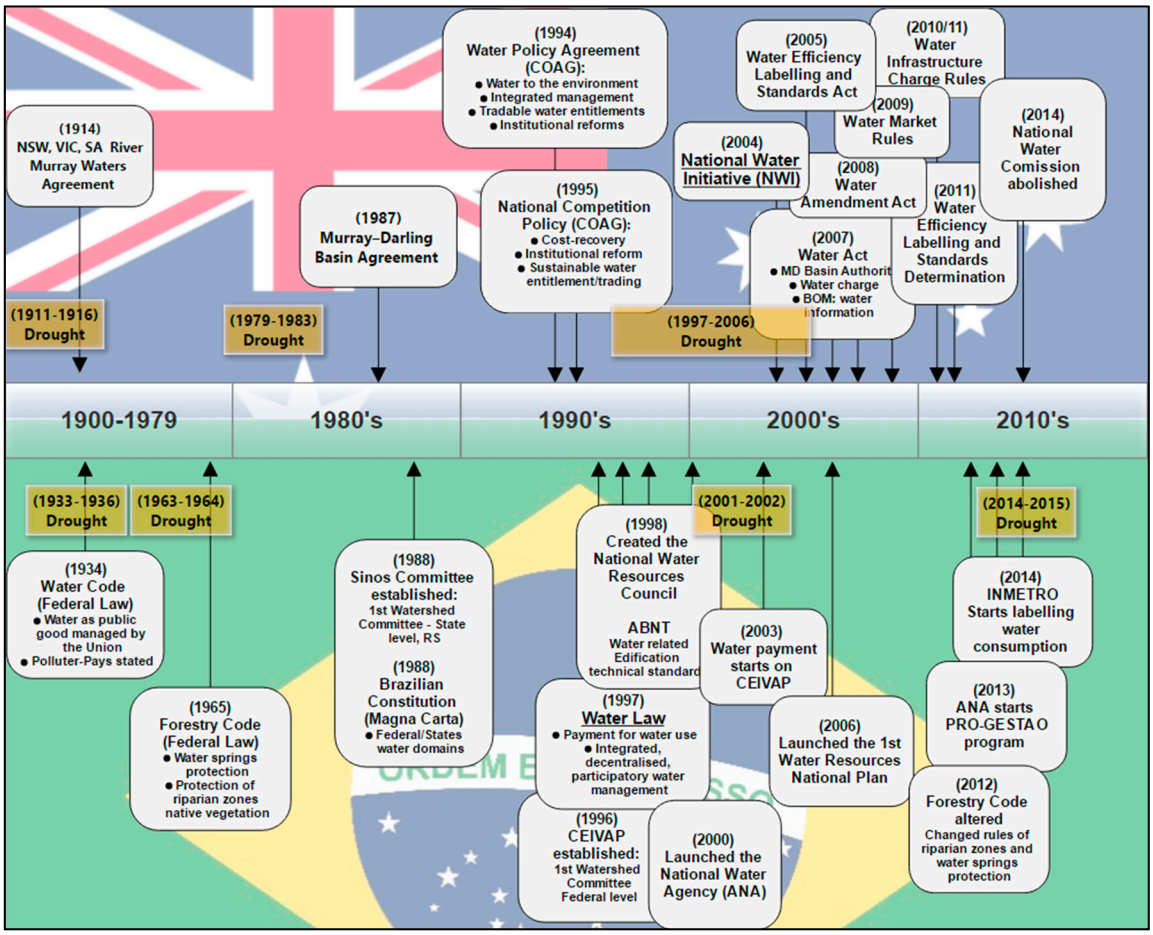

Figure 1. Timeline for water policies, programs, acts and initiatives: Australia and Brazil.

In spite of the interesting water management development in both countries, it is not within the scope of this paper to present a comprehensive historical view. In this sense, we focus on the most recent institutional changes and analyse the current system status. For a historical perspective on the

Australian and Brazilian water management we suggest the writings from Kildea and Williams [12] and Abers and Keck [13], respectively.

2.1. Australian Water Management Framework: Forged under a Water Crisis

The management of water in Australia's rivers is one of the most urgent public policy problems facing governments at every tier of the Australian Federation. Nevertheless, despite considerable Commonwealth power in relation to some environmental issues, the Australian Constitution (1901, Section 100) does not allow the Commonwealth (i.e., the federal level of government) to prevail over the rights of the "State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation". Thus, in the past the Australian Government has sought other mechanisms to gain State acceptance of the need to change water management policy [14].

An example of the enduring impact of State jurisdiction over water is well demonstrated in the Murray-Darling Basin which includes parts of the states of Queensland, New South Wales, Victoria and South Australia, and the Australian Capital Territory. One of the oldest registered agreements for collaboration on water management was formed in 1915 among the three most water-developed states, New South Wales, Victoria and South Australia. Since then, the Agreement has been modified to include all Basin states, reflecting its economic importance. The Agreement acquired legal force by parallel legislation in each jurisdiction. The River Murray Commission was established to coordinate water sharing, and dam construction and operation, among the states. Although the agreement worked for decades, the increase in water use brought other challenges related to the water/environment interface [15]. The rising salinity of water and lands, and algal blooms triggered new management arrangements, including a pioneer 'cap and trade' scheme targeting salinity reduction.

The situation in the Murray-Darling Basin was a major driver for the 1994 Council of Australian Governments (COAG, which is comprised of first ministers of Australia and each State and Territory and is used as a forum to negotiate and agree on national-wide policy), and the Water Policy Agreement, which stressed the importance of water for environment and the needs of integrated catchment management, and also established the water pricing and trade scheme. This era of water reform in Australia was prompted not just by changes in the water visions and values of societies in Australia and worldwide, but also by a neoliberal policy agenda regarding the role of the public and private sector in resources management in Australia.

This nationwide commitment was renewed ten years later by the National Water Initiative (NWI) in recognition of the "continuing national imperative to increase the productivity and efficiency of Australia's water use, the need to service rural and urban communities, and [importantly] to ensure the health of river and groundwater systems by establishing clear pathways to return all systems to environmentally sustainable levels of extraction" [16]. Under the Agreement, Australia's governments made commitments to:

- prepare transparent, statutory-based water plans with provision for environmental and other public benefit outcomes;
- complete the return of all currently over allocated or overused systems to environmentally-sustainable levels of extraction;
- introduce registers of water access entitlements and standards for water accounting;
- expand the trade in water;
- manage surface and groundwater resources and connected systems as a single resource;
- improve pricing for water storage and delivery; and
- meet and manage urban water demands.

In this context in 2005, the National Water Commission (NWC) was established under the National Water Commission Act 2004 as an independent statutory authority to provide advice to COAG on national water issues, and oversee and report on progress on water reform [17]. The NWC's primary role was to report on implementation of the NWI and how well it was delivering

against the expectations of full implementation. The NWC delivered biennial national water reform assessments in 2007, 2009 and 2011, and a final triennial assessment in 2014. A commissioned review of water planning in 2007, for instance, found inconsistent application across states, lack of coordination of water allocation planning with river health and urban water supply planning, and lack of coordinated assessment and management of surface and groundwater. The review also found challenges in returning over allocated systems to environmentally-sustainable levels of extraction, and to gaining public confidence through good engagement and sound transparent science that incorporates uncertainty [18]. Reasons for only partial progress were explained as lack of long-term data (especially groundwater data on which to make good decisions); lack of appropriate skills for this new approach among water planners, high turnover of staff (partly due to community conflict and politicisation in some locations), and lack of a coordinated learning approach across Australia.

Meanwhile, in response to ongoing concerns about the serious decline in the environmental condition and the inability of States to reach agreement on water sharing within the Murray-Darling Basin in particular, the Australian government took over control of high-level policy through the National Water Act 2007. In spite of this, water allocation and management is still for the most part, the responsibility of the States.

Following a review of the NWC in accordance with the Act, the Australian Government decided in 2012 to renew the NWC's role to provide strong, transparent and public reporting on water reform progress through its core monitoring, audit and assessment functions. The various assessments had consistently found that the NWI remained robust and relevant, and that it had catalysed substantial improvements water resource management, but it had not yet fully delivered its intended benefits. However, in 2014, following a change in government and in a move that was widely criticized, the National Water Commission Act 2004 was repealed, the NWC abolished and its functions dispersed among four different federal government agencies.

Pittock et al. [19] found that the NWI focus on legislative reform, independent regulatory agencies, and financial support contributed to public accountability, transparency and incentives for governments to follow through on their policies. The NWC's final recommendations include aspects relevant to this analysis, for example, that: "Governments should not backtrack on water reform"; "Governments should not mark their own scorecards on water reform"; "water quality objectives should be integrated into" water planning processes which have in most states focused on volumetric allocation, and that NWI principles should "guide the way water is allocated and managed for all users including extractive industries" ([17], p. 12). The new arrangements are seen as a major institutional barrier impeding progress towards a more consistent Australia-wide approach and better integrated water management.

2.2. Brazilian Water Management Framework: A System in Limbo

The National Water Act 1997 (No. 9433) replaced the previous 1934 Act. Under the Act, the National Water Authority was established in 2000 with a mandate to implement the National Water Resource Policy (NWRP) and the National Plan for Water Resources. The NWRP principles state that water management should allow for multiple uses of water; water is a limited resource with economic value; water resource management should be decentralized and involve participation by users and the community; and when there is a shortage of water, priority is to be given to human consumption.

Prior to the approval of the current Water Act 1997, water management in Brazil was dominated by the electricity sector, this hegemony being consolidated by the use of large water reserves for hydroelectric generation and its preferential water use through hydraulic operation of the reservoirs. Brazil's electricity sector involves large financial resources which supported the development of a technical group that influenced water use decision-making from the 1970s to 1990s. This influence encompassed the executive branch of government, responsible for the management of water and electricity during the period, as well as state-owned energy companies. The 1997 Water Act broke up the electrical sector hegemony through its recognition of the multiple uses of water resources.

The institutional organisation for water resource management in Brazil is highly complex. The Water Act defined two water management domains: the Federal level, for interstate or transboundary water basins; and the State level, for water basins contained wholly within the territory of one state. State water management systems were established within an overarching national framework, most of them maintaining political centralization, even though there was some administrative decentralization in a few cases [20]. Overall, the system continued the technocratic basis of management [21], which represented both a virtue and a weakness: on one hand, it would improve technical decision-making aligned with the State political agenda rather than through a primarily political approach; on the other hand, it represented an obstacle to socially inclusive participation in water management decision-making [22,23].

In the context of the Brazilian water resource policy, IWRM principles have been implemented mainly in the form of 218 State river basin committees and 10 Federal committees, 228 in all [24]. Appointed under the Water Act, or the State's legislation, these committees were intended as innovative decision-making spaces, characterized by a natural territoriality (the watershed), and incorporating a diversity of stakeholders (representatives from civil society, water users, and the government). In a legal and conceptual sense, these committees promote debates and mediate conflicts over issues related to water resources, approve plans for their river basins, and discuss the implementation of management instruments. In practice, however, the committees have been significantly challenged by political, technical and operational issues. As a result, the committees have, in general, been unable to promote a more robust agenda, which could help to build consensus in addressing problems like water pollution, financial sustainability and extreme events (floods and drought), among others. Much of the cause of the problem has been the unequal distribution of authority amongst the various stakeholders involved in the design and implementation of public policies. The principles of such a model are systematically corrupted by the domination of particular interests over others, usually favouring private stakeholders in an unequal manner [22,25].

Taking the context from another perspective, focusing on processes instead of outcomes, Abers and Keck [26] found that there was no general case in building the effectiveness of the committees. The 16 cases analysed by the authors showed a broad range of situations, however the success or failure to exercise practical authority depends more on how the stakeholders construct the organisation's relationship than resources available or the willingness of governments.

Two other institutions play a role in the Brazilian water resources management system: water councils and governmental water agencies, both of which are replicated at the State and Federal level. The water councils are comprised of representatives from the government, water users (companies) and civil society (academy, NGOs), appointed by each sector and established by law. Different from the committees, they are not limited by a river basin. They are collegiate structures responsible for developing and reviewing policies and for conflict resolution about water management. They also conduct discussions about inter-basin and inter-state issues, and even international and transboundary waters at federal level. The governmental water agencies are the executive part of water management, responsible to ensure implementation of the states' or national water plans, and liaising with the river basin committees. Reflecting the same problem as the committees and influenced by politics, these bodies have been unable to achieve the Water Act principles, especially those related to participation and decentralization. Most of the time, in the case of states, the water agencies have insufficient technical skills and the councils have become the political arms of the Government, far from representing the interests of all society, as intended.

2.3. Australian and Brazilian Water Management: Similarities among Differences

Despite the different political and institutional structures related to water management, it is possible to identify some similarities in the context and responsibilities in Australia and Brazil. Both countries were trying to evolve from top-down centralized systems based upon technocratic criteria towards more systemic approaches. In both cases though, the systemic approach was still

built under technocratic assumptions and functioning, giving way to less integrated management frameworks than might be achieved with different, more participatory approaches. As stated by law, the Brazilian system requires decentralization, shared planning process and the use of economic tools in a participatory approach, although practice and implementation do not always reflect these formal principles. With ambiguous decentralization derived from the latest changes, and the focus on cost recovery and a water market, Australian water management fits an economic/financial characterisation associated with strategic planning and use of scientific and economic tools. Roles and responsibilities of both systems are in Table 1, which is adapted from Young's [27] framework for comparative research in governance at national levels.

Table 1. Roles and responsibilities for water resources management in Australia and Brazil.

Roles	Responsibility	
	Australia	**Brazil**
Water related policies	Department of the Environment (federal level), State government agencies, coordinated through the Council of Australian Governments (national level).	Department of Water Resources linked to the Minister of the Environment, at federal level, with similar departments at State's level.
Advisory	The former National Water Commission (NWC). Functions are now allocated to other government departments.	National Water Resources Council at federal level and similar councils at state level.
Regulatory and Executive board	PC for National Water Initiative (NWI) assessment and performance; ABARES for water charging and rural issues; BOM and state/territory governments, for the water planning and urban waters.	National Water Agency (ANA) at the federal level and institutional bodies associated with Water Resources Departments at state level.
Watershed arrangements	Time-bound Stakeholder Committees are formed to provide advice during a basin water planning process under State legislation. However, most watersheds in Australia are covered by the equivalent of a catchment management authority or "Regional Natural Resource Management (NRM) body". The legislative basis and role in relation to water reform of these bodies varies from state to state. Separate to this is the Murray-Darling Basin Authority and associated Ministerial Council.	Watershed committees, created under the authorization of the National or State's water councils, with representatives from users (companies that have water entitlements), government and civil society, responsible for local (catchment) decision-making, mainly focusing on the water plans and conflict resolution.
Watershed administration, executive or implementation bodies	Implementation of water plans are via relevant State government departments. Urban water distribution is through quasi-government business organisations, which gain water provider licenses through the water planning process.	Water agencies as "quasi-govt" organisations, conducted by the watershed committees operating under contracts with the regulatory bodies.

While similarities remain at the upper management level between the two countries, the differences are more obvious at a lower level. Whereas the committees provide ongoing stakeholder participation as a formal permanent arrangement in Brazil, in Australia roles are less integrated. For water allocation, many watershed level stakeholder committees are disbanded once the water allocation plan is completed, as water is then distributed by the department according to the plan. Often, catchment management or Regional Natural Resource Management (NRM) groups have had and continue to have a long term role in planning and implementing integrated land-water management but in most Australian states they do not have a legislative basis and little guarantee of on-going funding (for further information see [28–30].

3. Method: Critical Analysis According to IWRM's Elements and Other Issues

Reinforcing the previously mentioned themes of coordination, equity and sustainability, IWRM "is a call to consider water holistically, to manage it across sectors, to ensure wide participation in decision-making", and " . . . to stop fragmentary approaches to water management and high-handed development decisions made for the benefit of a single user group or faction" ([31] p. 364).

As stated by Engle et al. [32], IWRM is fundamentally about governance arrangements and there is no universal model for designing the institutional structure and links. This has resulted in different arrangements in each country. These differences are noticeable in Australia and Brazil, where federal initiatives have conducted water resources management toward IWRM, but where state governments also have autonomy, at certain level, to implement water management processes.

Therefore, IWRM is a conceptual framework for which implementation is not a hermetic homogeneous process. It requires good contextualisation as each process is unique. In this sense, our analyses started with the quali-quantitative review of the IWRM Network and introduced some elements, based on the authors' experience and literature review.

Although Australian and Brazilian water management systems were reformed to embrace IWRM principles, there are still some gaps, generally for similar reasons. A recent comparative analysis made by the IWRM Network [33] showed the water management systems evolution from 2007 to 2011, as presented in Figure 2.

The primary data sources of the graphs in Figure 2 are the two global IWRM surveys (years 2007 and 2011) containing self-reported country survey data assessing the progress and outcomes of the application of integrated approaches to the development, management and use of water resources [33].

As illustrated by the graphs, both countries improved over time in most areas. In Australia's case, the main axes with improvement were concentrated on mobilizing financing and investment plans related to the water market and economic tools, from taking a "return-on-investment" approach. IWRM programs, knowledge sharing, and governance systems were consistently strong due to the long-term catchment management arrangements. Similar to Australia's NWC and COAG, in Brazil's case the improvements were led by the National Water Agency, with monitoring, knowledge sharing, investment planning and, lastly, the sub-national instruments set by the ProGestão program (see comments ahead). According to the UNEP review, both systems have a lack in terms of "other instruments" (Figure 2), especially those related to the integration of water with other issues, like land use and the environmental agenda. This is recognized as one of the most cited IWRM implementation problems for which Falkenmark et al. [34] propose a contemporary agenda to address this theme, especially in the water scarce countries.

Given the strengths and weaknesses revealed by this analysis, we chose three core elements of IWRM as a basis for further comparison of Australian and Brazilian water governance: integration, participation, and knowledge sharing. The authors consider these as essential areas of focus in moving towards a climate variable future. Each concept is further explained and discussed case by case.

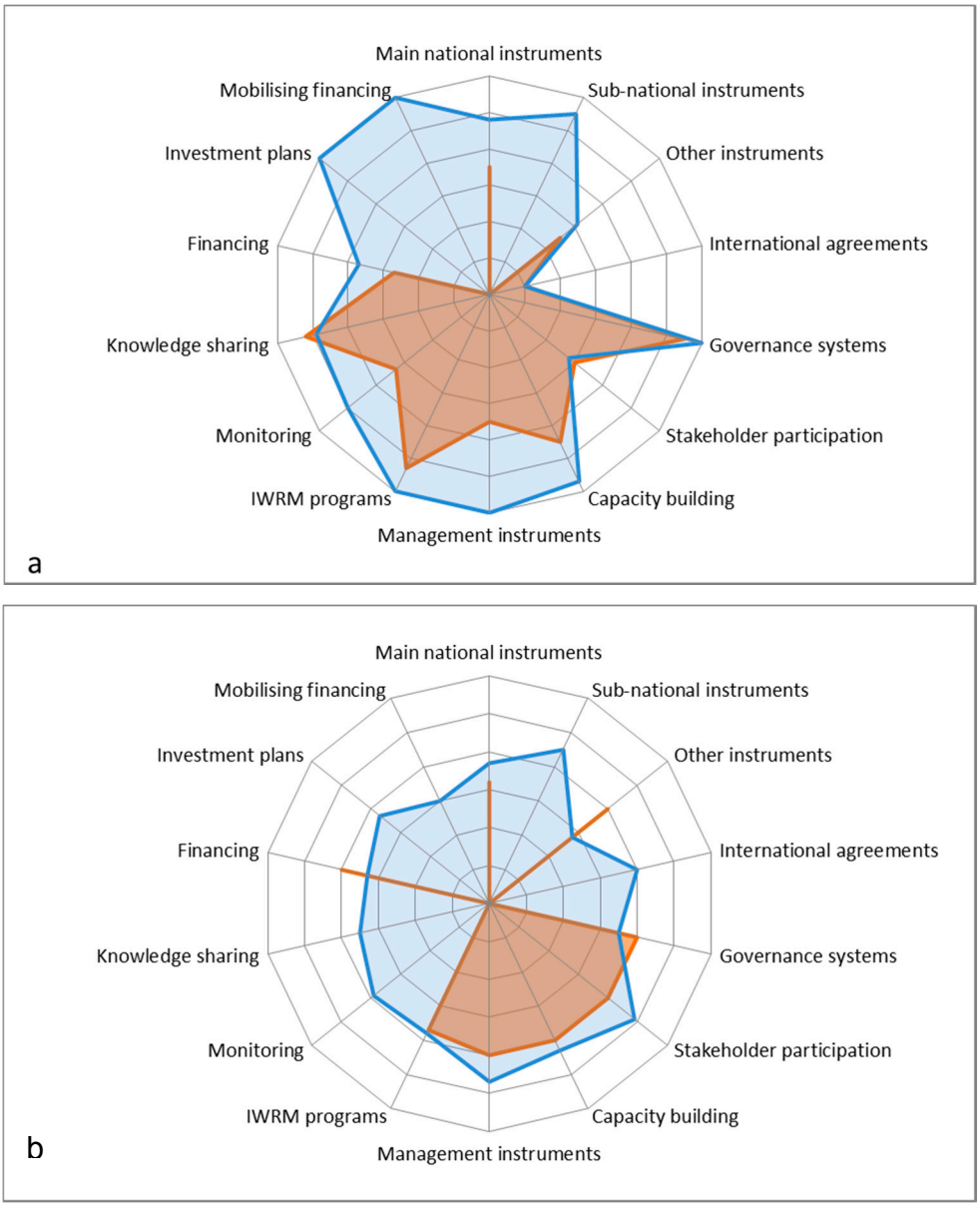

Figure 2. Integrated Water Resources Management (IWRM) implementation: (**a**) Australia; (**b**) Brazil. Orange: 2007; Blue: 2011. Source: UNEP [33].

3.1. Integration

"Integration" generally refers to adopting a consistent approach at various levels of the institutional hierarchy which enables focus around a catchment or river basin, and considers social, economic and environmental issues. It thus refers to spatial, institutional and temporal integration as well as integration of objectives [35]. Although widely recognized in principle, IWRM has been difficult to implement in practice because of the need to integrate a wide spectrum of themes and sometimes conflicting views between sectoral interests in a complex planning process, delaying resolution of water related problems. In spite of the criticism around IWRM (see [10,36–38] for more discussion), its elements have brought to water management a new approach, which is part of the present analysis.

The complexity of IWRM emerges from the need to properly articulate a great diversity of subsystems at very different levels [39]. While water management must be implemented at national, regional and local levels simultaneously, the water systems are also permanently changing and exposed to human pressures. An appropriate methodology for integrated water management encompasses,

therefore, not only technological tools but also governance strategies. This reflects the broadening scope of water management, and the term "integrated" implies an approach that goes far beyond traditional co-ordination and planning activities ([39], p. 2).

Regarding Australia, Hussey and Dovers [40] found that the challenges in implementing the NWI were many and exacerbated by Australia's federal system of government, the different systems of management and different sets of legal arrangements in each of the States and Territories, and the limited capacity of the Commonwealth to deal with the management of water resources.

Despite Brazil having a political system based on a nationwide agreement, with the federal Government having a more directive role, the same situation occurs, with strong asymmetry between states, and even between states and federal Government approaches and capabilities. Similar to Australia, a problem remains in the intersection of water policy with other agendas such as regional development, environmental, traditional communities' wellbeing and energy policy.

Two other challenges affecting both systems at different levels are the integration of water environments (surface waters, groundwater and coastal waters) during the planning process and the huge economic and political differences among the various entitled water users (energy, mining, agriculture, urban supply and waste treatment, and recreation) which have distinct influence and impacts within the water sector. Lack of integration of these aspects can result in long-term inefficiencies, inequitable trade-offs, and conflicts where the more empowered, wealthier, and better organized sectors prevail over others.

Furthermore, an 'integrated' approach imposes a holistic conceptualization of all the dimensions that are included within the sphere of water management, both the hydrological and the social, economic, jurisdictional and political relationships [41]. The international discourse has evolved towards this need for integrated views, by accepting that the complex land-water management systems must not only allow but encourage an intersectoral approach and dialogue.

The complexity of integrating land use planning and water management, accepting the cross-cutting dimensions of water, calls for an interdisciplinary approach. The "territorial" nature of water also implies consideration of different and evolving paradigms in planning theory ([39], p. 63). Better integrated land and water management also imposes a need to develop analytical frameworks and operational tools to assess the impacts of climate change in the water cycle [42]. Innovative conceptual discussions [42–45] aim to provide the policy making sphere with a more comprehensive approach to addressing the multidimensional challenges imposed by water management in the context of global changes (demographic, climate, economic).

3.2. Participation, Decentralisation, and the Decision-Making Process

Accepting, firstly, that IWRM is a means to an end and not an end in itself, there is a need to reinforce participation in the decision-making process that goes beyond mere consultation and/or information provision. While some authors argue that participation is not always necessary to achieve a good water resources outcome (e.g., [31]), in democratic societies, there is wide acceptance and an expectation that key stakeholders and the broader community will have a say in their future [46]. Good participation processes aim to identify stakeholder needs and impacts on the range of interests early in the process and improve decisions by including local knowledge to increase benefits and mitigate negative consequences, in order to maximise public benefit from the resource. Such processes must include local users and others with interests, including women, early in the process and indicate how their input has influenced decisions [47]. Therefore, the participatory approach is a seminal point of IWRM and its influence on the decision-making process needs to be well-addressed by both countries as it is highly important for future decision-making in relation to planning for climate change and responding to extreme events.

The traditional role of 'governments' as the single decision-making authority has in many instances been replaced by multi-level, poly-centric governance characterized by more deliberative, inclusive and bottom-up processes, including stakeholders in developing strategies [48]. However, a

suggested gap is in relation to analysis of the effectiveness of this new water governance engagement, when studying OECD countries, including Australia (Ibid).

According to the UNEP analysis (Figure 2a), stakeholder participation consistently remains the weakest area in Australia despite the fact that the water legislation of each state requires community consultation as part of the water planning process. This usually takes place in the form of stakeholder advisory committees established for the duration of the water planning process, as well as statutory requirements for advertising and public submissions on discussion papers and draft plans. While this approach has generally been considered effective, there is room for improvement: Committees should not be seen as a substitute for either targeted interest-group or wider engagement; powerful stakeholder interests can dominate if groups are not effectively facilitated; a range of engagement tools could be more proactively used; and those most intensively engaged expect to have some influence on decision-making or understand why they do not [18].

In addition, the inconsistent stakeholder participation arrangements in Australia between legislated water planning, and for the most part non-statutory catchment management agencies and NRM regional bodies, affects an integrated and participatory approach to natural resource management. While the system can facilitate water allocation decision-making, there is less opportunity for collective debate and resolution of complex issues (see more in the next topic). For instance, the establishment of water markets to support flexibility for water users and the movement of water to higher value uses has been a key feature of Australia's water reform agenda. In a review of Australia's experiences in establishing water markets, Young [14] noted that embracing competition and markets as a paradigm for water management has generated significant opportunities and wealth, but the gains have come at an environmental cost. When Australia embarked on its water reform journey and the development of water markets, it focused on the development of fully specified entitlement and allocation announcement systems and the reduction of barriers to trade. Considerable effort went into reducing transaction costs, speedy adjustment and promoting efficient investment, but less effort went into resolution of an associated set of accounting and allocation issues critical for the maintenance of river health, wetland health and water quality.

Regarding the Brazilian case, in spite of the participatory and decentralized approaches of the national water policy (represented in Table 1 by the advisory 'watershed arrangements'), the most important players, with a privileged representative space, are the water users (companies that hold a water entitlement), which held 40% of the watershed committee's seats. With strong economic power and network capabilities, these stakeholders unbalance the system with their private interests gaining priority to the detriment of the overall public good. In addition, the role of civil society is shared by a small group of representatives that represent a broad range of interests, which makes consensus a real challenge. Such an unbalanced collective decision-making process is reflected in decisions, imposing a lethargic effect on the system, when faced with a government weak in water related issues. For example, the lack of consensus in the committees in relation to financial sustainability through the implementation of a water charge has resulted in failed implementation of the user-polluter pays principle, due to the unequal political weight of the representatives in the committees, where water users usually have a strong and well organized position against this proposition. Moreover, when a water charge is approved by some committees it has been a very low price that does not enable creation of a viable robust water agency to give technical and operational support to the collegiate. As a consequence of strong political polarisation over the last decades, both federal and state level governments in Brazil have moved towards an autocratic decision-making process. That is reflected in Figure 2b, where "governance systems" have a low score.

3.3. The Role of Knowledge and Information on Water Governance under Crisis

Accurate and shared knowledge and information are key components of a good IWRM decision-making process. Participatory processes rely on participants being adequately informed of implications of possible options, as well as having trust in the process through information transparency.

Important considerations include the uncertainties that arise through lack of adequate long term historical data, and the challenges in predicting future climate, on which hydrodynamic modelling is based [49–51].

Recent experiences in water management, such as those from the Murray-Darling Basin, have increased community awareness of the risks and consequences of water use decisions. Increasingly, communities expect developments to not only have acceptable environmental impacts but also deliver social and economic benefits [15,22]. Furthermore, non-government organizations and individuals are better trained, connected and equipped to monitor decisions [52]. Together, these trends are increasing pressure on decision-makers.

However, there is another face of the technical approach in water management. For Lemos et al. [53] the "technocratization" of water resource management challenges the basic principles of the democratization of participative processes, as those with the knowledge in turn can seek to take advantage of their privileged situation. In a substantive democratic decision-making process, knowledge must be available to everyone. Hence, an effective, participative water management system will be most effective when the use of this knowledge is transparent, effectively accessible, and made understandable to all committee members and society overall [54].

Regarding the role of information and knowledge in setting the water resources agenda, a survey of basin committee members in various parts of Brazil reveals that the committees have been using technical and scientific information, for example, on water quality, hydrological models and environmental impacts. Most of the members of these committees believe the use of such knowledge facilitates the deliberative process. Nevertheless, these members realize that the use of this information is the main source of inequality in the decision-making process, being more significant than inequalities in economic or political authority, and creating an obstacle to the capacity of members to participate and influence the decision-making process as well as others [23,53,55]. Likewise, in Australia, Baldwin [56] reported committee members that were part of the Lower Balonne water planning process as feeling intimidated or ridiculed by more powerful committee members if they questioned facts or models. While this may not be common with all such committees, it is incumbent on government water planners to ensure this does not occur.

Another key element regarding information and knowledge is transparency. Initially just an accessibility concern about how information reaches the stakeholders, the concept is broader, including issues related to integrity and legitimacy. According to Stalgren [57], the concept is used today to break the knowledge and power asymmetry in water management decision-making. A review of water planning in Australia found many examples of good practices that contributed to community's confidence in water planning, such as having independent expert peer review of models, scientific studies, and socio-economic assessments; ability to appeal a plan in some states; and acknowledgement and response to public submissions [18]. However, it was noted that there was still room for improvement in terms of greater public involvement in exploring and assessing options for trade-offs, wider ability for Parliamentary review of plans, and wider avenues for appeal. In Brazil, a recent study analysed the transparency of the states' water bodies, focusing exclusively on the availability to society of essential information about water management [58]. The authors pointed out that 75% of the states received scores below 4 (on a 0 to 10 scale) and the better ranked states scored 6.5. Those results showed the low transparency level of water management in Brazil, in terms of essential information given to society. This can contribute to a low level of participation in the first instance and, at the most negative, to a high level of corruption in water management. This situation can be worse in times of crisis, when emergency actions can drive more centralized and non-transparent decisions, in contrast to with the ideal governance needed to face complexity and uncertainty in changing times.

4. Coping with the Water Crisis under a Changing Climate: Lessons to Learn

4.1. Water Governance in a Climatic Change Scenario: Addressing Adaptation

Climate change has emerged as one of the most important topics to be addressed by water governance. The unprecedented extreme events of floods and droughts affect water management in diverse ways, with the level of complexity and uncertainty being a key challenge. Focusing on severe droughts which have affected both Australia and Brazil in the last decade, it is instructive to analyse the water management systems with respect to their potential capabilities in facing future crises.

One key factor is to understand the differences between Australia and Brazil regarding the perception of the crisis and the future challenges. Freitas et al. [59], when studying climate change adaptation in a Brazilian region, found three factors that can constrain a forward movement in local societies: (i) the perception of a signal and threshold of concern (actual climate change); (ii) leadership for change and adaptation; and iii) the institutional context (and inertia). In relation to the first factor, in contrast to Australia whose society lives in a water scarce context, the Brazilian population as a whole, lives in an "abundance think" social paradigm, which was only recently broken during the latest severe drought. The same occurs for other aspects of climate change, currently not in the society's knowledge spectrum in Brazil. With respect to the second factor, leadership for change and adaptation, some argue that the IWRM framework, once adopted, could create an inflexible structure, particularly due to over consulting of stakeholders [32], which can lead to decision paralysis. Given Brazil's water committees and water councils at state and federal levels, and the criticism of lengthy consultation and delayed decisions about the Murray-Darling Basin in Australia, this risk is real. In terms of the third factor, institutional inertia, recent research conducted by Barbosa et al. [60], in conjunction with water management stakeholders in São Paulo state (Brazil) has pointed out that, for them, the institutional and governance challenges are more important than the technical/financial ones, in order to achieve better water management.

Recent debate has brought back the criticism about IWRM, especially when addressing complex issues like climate change. In this context, Engle et al. [32] made a comparative analysis with IWRM and Adaptive Management (AM) in order to understand their roles on water management when facing problems that need fast and efficient decisions. According to the author, the dominance of a small number of technical people making decisions in a more centralized system can facilitate flexibility for a fast decision in stressed times, an important aspect of AM. On the other hand, the integration of a broader diversity of stakeholders with different perspectives under more decentralized models enhances legitimacy and brings more locally relevant knowledge to the decision process (important tenets of IWRM), but often at the expense of the flexibility maintained by a smaller, technical team [32].

Expanding the discussion, Schoeman et al. [61] concluded that a combination of all approaches—they included Ecosystem Based Approach in addition to IWRM and AM—and a relaxing of the tensions between them, could drive a better solution for water management under the complexity and uncertainty of our contemporary challenges.

4.2. The Role of Demand Management in Water Crises

The technical-bureaucratic inheritance of both the Australian and Brazilian water management systems and scientific basis of decision-making forums raise an important aspect relating to water infrastructure: the predominance of investments in boosting supply to the detriment of action to reduce demand. The "engineering of supply" has long dominated water management and the indirect damage, social costs, and environmental impacts—externalities—associated with large infrastructure works has been devalued in investment analyses [40,62]. The evaluation scenarios for the expansion of water consumption—and this is also true for energy and other inputs—generally do not consider more effective measures for rationalization and efficient use, generating over-estimated figures that in themselves legitimize massive investment in infrastructure.

Various recent examples illustrate this situation in both countries. As a result of the drought and critical water supply for the city of Brisbane in Southeast Queensland, Australia, the State government reacted by constructing major infrastructure works such as a desalination plant, recycled water plant and pipelines interconnecting major cities and towns (a "water grid"). The Queensland government also proposed an inefficient new dam and purchased the required land prior to final approvals, displacing a productive rural community. In the end, the Commonwealth government rejected the proposal due to potential impact on endangered species under its jurisdiction, but not before immense social and economic costs. This was in spite of assessments which showed that demand management and installation of household rainwater tanks could meet current and future demand with far less expense [63]. Furthermore, the constructed works have seldom been used since because they were costly options compared to the pre-existing water sources once the drought broke.

In Brazil, relevant examples include the water diversion work on the São Francisco river, the final benefits of which are concentrated in the cities in the northeast of the country, where water consumption is extremely wasteful; the construction of large hydroelectric dams in Amazonia, which will generate energy to supply inefficient consumption in the southeast region of Brazil and some industrial sectors which have historically benefitted from energy subsidies [62]; and, recently, the water diversion project in the Paraíba do Sul watershed to the metropolitan region of São Paulo city, to cope with increasing water demand and a severe drought event; among others. Such investments have favoured a selective group of stakeholders in the production chain for decades: they include large infrastructure companies and political agents whose power is hard to measure, as it stretches through the structure of the State and reaches the limits of the public and private spheres. The recent political struggles in Brazil, with imprisonment of politicians and CEOs of big infrastructure companies reflect those biased relationships and problems derived from highly centralized and decision-making processes which lack transparency.

The counterpoint to this infrastructure approach is based on studies that have demonstrated the capacity of demand management mechanisms to solve the restrictions on the supply of natural resources, especially water [7,64,65]. According to Low et al. [66], who analysed Greater Melbourne's drought adaptation plan and results, the investments made to reduce water demand through residential and industrial water conservation programs and restrictions have been effective during drought times and are holding steady years later. During and after the Millennium Drought period, the city reduced its household water demand by 50%. It is thus important to break the short term planning approach adopted in crisis times to retain the most relevant measures in the long run. Regarding Brazil, during the last drought (2014–2015), some demand management instruments were successfully used, like the adoption of incentives to reduce water consumption and fines for those who exceed a defined water quota. However, these instruments were abandoned once the critical period was over, indicating the short-sighted nature of the official initiatives in water management.

Gleick and Heberger [67] noted that even in the midst of these challenges and reforms (many of which addressed water supply problems in the capital cities), the Australian government continued with plans to restore rivers and wetlands by cutting withdrawals from the Murray-Darling Basin by 22–29 percent. They urged the need to tackle the difficult policy issues, even in favourable water times, before a disaster strikes, observing that as the climate continues to change, this pre-emptive action "may help ease the impacts of unexpected and severe shocks that now appear inevitable" ([67], p. 14).

4.3. Multi-Level Governance: Devolvement to the Regional Level

The dispersion of authority away from the central government deserves attention given the multi-level nature of governance regimes both from an analytical and a normative perspective ([68], p. 357). Pahl-Wostl et al. refer to research on how federalism has explored delegation of authority from the central state to lower levels and analysed the performance of different kinds of political systems from more centralized (e.g., France) to more federal (e.g., Germany, Switzerland) structures. This applies both to Australia and Brazil. Given the complexity of multi-level water governance

regimes, new formal institutions have been introduced in most countries of the world following the hydrological principles to problems of fit between administrative and biophysical boundaries, such as the river-basin administration bodies. However, Pahl-Wostl et al. argue that the introduction of the hydrological principle is only one of a variety of barriers to effective vertical coordination of governance levels, with the consequent difficulty of articulation between the basin scale and the traditional administrative boundaries (e.g., spatial planning, agriculture). Besides barriers for implementing integrated management approaches, this can also create an impediment for the adaptation to climate change which requires effective vertical coordination. Innovative solutions to overcome potential barriers for vertical coordination are in high demand ([68], p. 358).

In both countries, the federal Governments have integrative issues that have to be addressed at a local/regional watershed level. That is the case when there are international compliance demands, or multilateral compromises required to achieve goals. That is also the case of climate change adaptation plans, which usually start at national level, in a top-down approach [69].

In Australia, the NWI established an agreed set of principles for water management but, critically, it incorporated sufficiently flexibility for each jurisdiction to determine how they would implement those principles. Further, while there were financial inducements from the federal level to support implementation—including the "10 point, 10 year, $10bn National Plan for Water Security"—there were no financial penalties for failing implementation. Together this created a balance of top-down policy and support that matched a bottom-up practical capability for implementing on-ground reforms through the states and territories.

The increased involvement of the Australian government in water policy at the national level also provided leadership, encouragement, financial support and the need for the water managers from all jurisdictions to engage in a more comprehensive dialogue about water management challenges and opportunities. This enhanced networking between water managers and between jurisdictions at the operational level encouraged the sharing of experiences and ideas, and innovative solutions to mutual problems.

The Brazilian National Water Agency similarly launched the ProGestao in 2013, a program to improve intrastate cooperation aiming to achieve better integration among the several water themes. Considered a national covenant for water management, the program supplied funds from the federal budget for infrastructure management, mainly focused on water information and human resources. As a counterpart, the states, whose participation is voluntary, have to achieve some goals according to strategic targets, set by the National Water Agency (ANA) after rounds of consulting with the states' councils of water management. After three years, the program embraced all Brazilian states and established a milestone in water governance, giving the states the possibility to solve basic entrance problems which were obstacles to set a minimum water management agenda. That helped to achieve more homogeneity among the states' water management scheme and fill a known governance gap:

> **Brazilian program ProGestão, 1st cycle results:** The ProGestão program was established to build commitment between the states and federal government over the water management agenda in order to overcome common barriers and to promote the sustainable use of water. Launched in 2013, the program is finishing its first cycle (2013–2016), in which 9 states participated. The program consists of voluntary money transfer from the National Water Agency (ANA) to the participating states based on achievement of previously established goals in water management. These goals were divided in two types: (i) cooperative and interactive management goals involving state and federal level; and (ii) state water management empowerment. The first type embraced mainly the national database of water entitlements and users, and the state's water related monitoring scheme. The second type involved water policy implementation, including the legal framework, planning and information tools. The goals were adopted with a progressive scope according to the level of water management in the several states (4 groups of goals, from the less advanced to the most advanced states related to their water management agenda).

> At the end of the first cycle, an assessment made by ANA pointed that more than 85% of all goals were achieved with the investment of approximately US$5 million in the 9 states. Meanwhile the results have given light to the general difficulties faced by the states in implementing the water policy, especially those related to the lack in human resources and financing schemes, in addition to a strong bureaucracy. All participant states agreed with the importance of the program and its maintenance. (Source: ANA [70]).

4.4. The Role of Knowledge and Social Learning in Dealing with Uncertainty

Dealing with complexity, uncertainty and transparency emerge as shared needs and responsibilities for government, developers, and the community so that good decisions can continue to be made—and be seen to be made. The Northern Australia Irrigation Futures (NAIF) project (2003–2010) sought to learn lessons from mistakes made in the management of water resources in southern Australia, principally the Murray-Darling Basin, to help avoid a repeat of those problems in the north. NAIF was a collaboration between the Australian, Queensland, Northern Territory and Western Australian governments, the Cooperative Research Centre for Irrigation Futures, Land and Water Australia, the National Program for Sustainable Irrigation and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). It aimed to develop new knowledge, tools and processes, including an overarching framework, to support debate and decision-making regarding irrigation in northern Australia [52]. Initially, a framework based on sustainability indicators and management criteria at a range of scales was proposed. However, as issues such as complexity, uncertainty, resilience, risk and adaptive management emerged through the research, focus shifted away from a simple set of biophysical indicators to frameworks to support communities and decision-makers deal with complexity and uncertainty in a comprehensive, transparent and inclusive way [71]. This increasing focus on social learning is reflective of the generally increasing awareness of the importance of social learning in water resource management. As Pahl-Wostl et al. ([68], p. 1) explained, the introduction of the term "governance" signalled a change in thinking about the nature of policy. The notion of government as the single decision-making authority exerting sovereign control over its citizens has been replaced by multi-scale, polycentric governance approaches that recognize the contribution of a large number of stakeholders, functioning in different institutional settings.

The need for a coherent and internally consistent way of water management is recognized by all. However, Gupta et al. [72] point out that the diversity of levels at which decisions are taken and the diversity of actors that make decisions in a diversity of local contexts imply that such coherence may not be easy to achieve. They argue that "a critical element of adaptive or integrated governance is to engage stakeholders in decision-making", although 'if stakeholders are engaged at different levels, they may also make different choices on the basis of their specific historical or contextual circumstances and different power configurations' ([72], p. 577).

As the importance of social process in irrigation decision-making became more prominent, the NAIF focus shifted towards a framework or suite of simple tools and processes that could support communities and decision-makers deal with complexity and uncertainty in a comprehensive, transparent and inclusive way. Recognising the rapid growth in the development of on-line technology that utilizes new approaches to learning and supports communities of practice in the resolution of complex problems, NAIF developed a prototype sustainability framework for the Lower Burdekin River, comprising an Ecologically Sustainable Development Component Tree system to help identify issues relevant to future decisions, a web-based catchment knowledge platform to support knowledge sharing and processes for improving the integration of science, policy industry and other stakeholder interests, principally through the Lower Burdekin Water Futures Group.

In Brazil, one of the most relevant social learning and cooperative approaches to conflict resolution, happened in the Paraíba do Sul watershed with the first water committee established at federal level. The entire basin encompassed three of the most important states, which account for almost 50% of the Brazilian GDP. Several activities in the basin are water dependent, mainly in the industrial and

domestic water supply sectors. The basin also included hydropower plants and irrigation districts, making water management a complex mosaic of interests. In 2004, when the region faced one of its most severe drought periods, several conflicts related to water allocation emerged, making the watershed committee a legitimate place for discussing them. Social learning had an important role at that time, making it possible to organize a cooperative network and establish a set of shared goals involving the main stakeholders in the process [73]. A substantial social learning process achieved by technicians acting inside the watershed committee for years, and the social network built across the participant states, allowed them to organize a well-established drought task force responsible to generate the information base for decision-making on water allocation [25]. The new allocation scheme was adopted by the water users, especially impacting on the operation of hydropower dams, and it was enough to minimize the economic losses during the critical period. Once it was successful, the allocation scheme was set as the new standard for critical times. According to Engle et al. [32], the success of this arrangement was based on the flexibility provided by the long run work and the capability to transfer decision-making to other stakeholders, in an accreditation process, in times of crisis.

5. Conclusions

Australia has undertaken a major water reform agenda over the last two decades, with many successes and rewards, but high costs have also resulted from some of the mistakes that have been made. The devastating floods of 2010 and 2011 relieved Australia of one of its most challenging droughts, and at the same time raised a new set of questions about how well Australia's water policy and practice was prepared for the inevitable cycling between droughts and floods that has been a persistent feature of the Australian landscape—a pattern that is likely to be exacerbated through the impacts of climate change.

In Brazil, the development of the water management system has reinforced a bureaucratic organization that favours primarily technical knowledge, restricting access or even blocking public participation that is supported by legal principles. This has resulted in a civil society participation gap, which has reinforced the role of the main users (who hold the water entitlements) and the government in the decision-making system. The political bias and contradiction of the essence of the water law was exacerbated during the recent water crisis. Even though this technical and scientific approach of centralized decision-making can facilitate the institutional shift towards climate change adaptation, participatory approaches, as per IWRM principles, need to be improved in order to legitimize both the process and the actions. Furthermore, decisions should be based in a transparent and well informed process and take into account the lessons from similar situations worldwide in order to avoid unnecessary or ineffective measures. As demonstrated in the Australian case during the Millennium Drought, the most effective initiatives were those involving government, the private sector and society at large to achieve a more sustainable consumption pattern in all sectors.

Even though Australia and Brazil have made significant progress in their water management legal and institutional frameworks, and towards good practices achieved by IWRM implementation, both need to improve the system's resilience. Our analysis suggests a need for better integration of water policy environments (surface, ground and coastal waters) and between water and land management during the planning process. One key factor for building this resilience is the engagement of civil society in a way that balances private interests (both licence holders and infrastructure builders) and the public sector. Even though participation does not guarantee resilience per se, one of its positive consequences—sharing knowledge including with the media—can help to avoid backward steps associated with political changes.

In terms of water governance, the heterogeneity of both political systems with federal and state arrangements has created similar opportunities to implement multi-level programs. Despite the need for improvements, this kind of multi-level cooperation seems to be a promising instrument for the future of water management. That can be especially interesting in the context of climate change

(e.g., extreme events), for which it is not only important to set an adequate institutional framework but also to lead in addressing the adaptation agenda.

This paper sought to compare the contemporary water governance frameworks of Australia and Brazil in relation to three elements of IWRM: integration, participation, and information/knowledge. We have found that in relation to each of these elements there is much to learn from the Brazilian and Australian experiences in water reforms—both from the successes and from the failures—but it is important to understand the social, economic and environmental contexts within which they took place. Some of the learnings may be transferable, or adaptable to other jurisdictions, and some may not. Continuing to develop the capacity and willingness of researchers and policy makers to work together, and using comparative rigorous and multidisciplinary methodologies to sift through the growing body of good and bad experiences in water reform for the gems of wisdom, can make an important contribution to addressing the growing challenges of water management around the world.

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