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Addressing Urban–Rural Water Conflicts in Nagpur through Benefit Sharing

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Abstract: Urban and rural areas often meet their water demands from a shared stock of finite water resources. Against the changing climate, the rising water demands in fast-growing urban areas are leading to increasing water-use conflicts with the co-dependent rural areas. Although poor water governance is frequently cited as the key reason for such urban–rural conflicts, it is also recognized as a potential pathway to resolve them. In the case of Nagpur Region in Central India, water stress has today become a subject of serious concern. The water demands in Nagpur City are primarily met through the multipurpose Pench Dam on priority, but the recently declining water availability has raised undue concerns for irrigation in the Pench command areas. To substantiate the limited understanding of ongoing water conflicts in the wider Nagpur Metropolitan Area, this study analyzes a specific set of secondary data related to the history of the Pench Project and its water utilization trends. By uncovering the periodic decline in irrigated area and the increasing groundwater use for irrigation, the cross-sectoral and transboundary implications of increasing water transfer to Nagpur City are revealed. To address these concerns, this study then suggests feasible governance strategies based on benefit sharing and multi-stakeholder engagement.

Keywords: urban–rural; water conflict; water stress; water governance; benefit sharing; multi-stakeholder engagement; Nagpur

1. Introduction

Water stress—a component of water scarcity—has now become a buzz word in the wake of growing population, rapid urbanization, and changing climate [1–4]. Against the widespread spatial and temporal variation in the availability of freshwater resources [5], water stress refers to a situation wherein the demand of fresh water exceeds the available quantity during a specific period of time or when poor quality restricts its usage [6,7]. A recent report by the United Nations [3] highlighted that more than two billion people today live in countries that are experiencing high water stress. Several global research agencies [1,8,9] have further pointed that the levels of physical water stress will continue to increase with the growing population, economic and land use change, and changing climate [10,11]. Although the concerns of water stress are escalating around the world [12,13], Asian countries, in particular, are projected to experience acute water shortage by 2050, mainly due to their high demographic growth and lifestyle changes [14,15]. Large developing countries like India are already experiencing severe water stress [16–18], due to their high freshwater withdrawals [19,20] and declining per capita water availability [21,22].

As of 2018, more than 55% of the world's population (around 4.2 billion people) was already residing in urban areas, a proportion that is due to reach 68% by 2050 [23]. Against this rapid growth, the water demands in urban areas are projected to correspondingly increase by 50 to 80% [24–26]. While one in four large cities globally is now facing direct water stress [27], the proportionately increasing demands for water-intensive resources—like food and energy—are also raising indirect water-stress concerns [5,11,28]. Addressing the water–energy–food nexus has therefore become central to achieve sustainable urban development as the demand for all these three inextricably linked resources is increasing [29–31].

Water use conflicts have for long been recognized at the national and international levels. However, the declining freshwater availability has today become a subject of concern at local level as well [32]. The growing water demands in urban areas are often met by sourcing water from rural watersheds, mainly from the reservoirs constructed for irrigation purposes [26,33–37]. As the drinking-water demands take precedence over other water uses by law, the fast-growing urban areas receive priority water allocation even in the water deficit years [38]. The growing water appropriation by urban areas is thus leading to increased conflicts with rural areas, as agriculture is by far the largest consumer of freshwater resources worldwide [3,39,40]. The concerns of urban–rural water conflicts have also recently gained prominence in the scientific literature [41,42].

Poor water governance is frequently cited as the key reason for urban–rural conflicts. However, it is also widely recognized as a part of its solution [43,44]. Several studies have recently emphasized on transboundary water cooperation and conflict resolution mechanisms for regional balance and stability [45–51]. The importance of urban–rural linkages and partnerships have also been recognized in the recent global policy agreements, including the Sustainable Development Goals (SDGs) [52] and The New Urban Agenda [53]. Target 6.5 of SDG 6 (Clean water and sanitation) emphasizes on implementing Integrated Water Resources Management (IWRM) through transboundary cooperation and Target 11.A of SDG 11 (Sustainable Cities and Communities) aims to support positive urban–rural linkages. By defining 10 entry points to urban–rural linkages, The New Urban Agenda also reiterated the importance of integrated territorial development.

Despite the growing recognition for transboundary cooperation, the policy mechanisms to address the urban–rural conflicts at local level remain to be underdeveloped [33,51]. The inter-sectoral allocation of water is also largely based on economic principles [41], but the relationship between long-term urban economic growth and the water use trends are yet to be examined in-depth [54]. Perhaps, a great deal of research is being done to understand the urbanization trends, growing water demands, etc. But then again, most of these studies are focused on generic conceptual issues (frameworks, models, etc.). The cross-sectoral and transboundary impacts of increasing resource appropriation by urban areas have been a subject of far less attention, and very limited research (e.g., [34,42]) has been done to address the localized water conflicts at policy and governance levels.

With an aim to bridge the identified research gaps, this study discusses a specific case of Nagpur in central India, which is projected to be the fifth fastest growing city in the world from 2019–2035 with an average Gross Domestic Product (GDP) growth rate of 8.41% [55]. The city is presently undergoing phenomenal transformations in their levels of infrastructures paralleled by a growing demand of freshwater resources. At the same time, the urban and rural areas in wider Nagpur Metropolitan Area (NMA) have been experiencing acute seasonal water stress in recent years. The media reports have highlighted the noticeable concerns of declining water levels in reservoirs [56–58], drying water sources [59,60] and fluctuating water supply [61–65]. However, there is a very limited understanding of these issues from a wider regional as well as interconnected perspective. It is clear that the water supply for Nagpur City is largely met through the multipurpose Pench Dam, but not much is researched about their cross-sectoral and transboundary links with the co-dependent rural areas. This indicates the need for an in-depth background study of the Pench Project to first determine the root cause (emphasized by Gleick [66]) of ongoing urban–rural water conflicts in NMA. The recognition of other co-dependent sectors across different administrative scales will provide a wider context for holistically addressing the water conflicts through feasible governance measures.

In lines to that, the three key objectives of this research are as follows: (1) to study the historical timeline of the Pench Project, (2) to investigate the cross-sectoral and transboundary implications of increasing water transfer to Nagpur City, and (3) to suggest feasible directions for addressing the growing urban–rural water conflicts at policy and governance levels. It is important to clarify that the term 'conflict' primarily holds a negative connotation (like violence and threat) [35], but the authors have used it in a fairly wider context for peacefully addressing (like through policy reforms) the cross-sectoral (like between urban domestic and irrigation) and transboundary (like between Nagpur City and surrounding rural areas) concerns in NMA. Through this study, the authors seek to address the following research questions: What is the cross-sectoral and transboundary implication of increasing water transfer from Pench Dam to Nagpur City? In what ways can improved water governance address the growing urban–rural water conflicts in NMA? This study is motivated by—what the authors believe is—the urgent need to address transboundary water conflicts at local level.

The remaining part of the paper is structured as follows. Section 2 discusses the state-of-the-art scientific literature on urban–rural conflicts and water governance, setting up a theoretical foundation for the conducted research. This section also discusses the significance of benefit sharing measures and describes a good practice of Kanagawa Prefecture (Japan). In Section 3, the authors introduce the case study area of Nagpur before elaborating on the current water-supply concerns in the city. Section 4 precisely explains the research methods adopted for the study. The detailed analysis and results are presented in Section 5. Based on the research findings, the authors suggest feasible governance strategies for addressing the ongoing urban–rural water conflicts in NMA in Section 6. Lastly, Section 7 summarizes the key conclusions and underlines the research limitations.

2. Literature Review

For reviewing the state-of-the-art scientific literature, the authors conducted a methodical search on selected databases—mainly on Scopus and Science Direct—using key search terms like 'urban–rural', 'water conflicts', and associated variants. The research also took into consideration the online grey literature, academic research, and related websites on the concerned subject. Even though a considerable amount of literature has been published on water conflicts, the authors identified and mainly reviewed the articles related to policy and governance aspects of water resource management.

2.1. Urban–Rural Water Conflicts

Urban and rural areas are geographically dispersed, and they exist as independent entities with varying characteristics (like demographic, economic structure, etc.) [67,68]. However, they are closely interlinked through a variety of spatial and sectoral linkages in form of water, food, energy, etc. [69–71]. While water resources (both surface and subsurface) form an important linkage between urban and rural areas, the expanding urban boundaries and rapid urbanization trends are straining the finite stock of available water resources. Against the fast-growing water demands in urban areas and its declining availability, the competing claims on the limited water resources are leading to increasing water use conflict between a range of water users across different sectors (agriculture, industry, etc.) along the urban–rural interface [24,26,72].

Water conflicts at interstate or international level have been recognized for a long time. However, the intrastate conflicts (occurring within the boundaries of a state) have recently gained increasing prominence due to factors like changing population dynamics, changing consumption patterns and climate change [73,74]. An increasing amount of quantitative and qualitative literature is now being published on localized water conflicts between actors like rural farmers, industries, upstream–downstream water users, poor people, etc. [35,75–78]. Moore [32] explained that water conflicts often arise over shared river basins and can take various forms ranging from organized violence to political disagreement. However, they could broadly be categorized into at least four distinct types, namely 'Infrastructural' (like dam construction), 'Allocative' (like disputes over water allocation), 'Distributive' (like water pricing), and 'Qualitative' (related to water quality degradation).

2.2. Water Governance Challenges and Opportunities

Urban–rural water conflicts are driven by the fact that urban water demands are by law prioritized over other water uses like agriculture and industry [38,79]. Even during the water-stress situation, urban areas receive a significant proportion of available fresh water to meet their drinking-water needs [76]. While the world is progressively more urbanized, these localized water conflicts are likely to increase without any major reforms to foster transboundary cooperation.

To accommodate the trans-regional nature of river basins and to maximize the social and economic welfare, the importance of IWRM approach has been globally recognized since the 1950s [80–82]. However, the integrated management of shared water resources remains to be complicated, as the river basin boundaries do not usually comply with the administrative boundaries. Christophe and Tina [83] underlined the core problem of institutional fit and interplay, as the conventional pathways of political accountability do not necessarily apply along the river basins. The study also underlined the key factors of political interests, resident preferences, relative income levels, etc. that drive a municipality's support towards a river basin plan.

Over the years, a variety of other governance approaches ranging from regulatory instruments (permits, bans, etc.) to economic instruments (subsidies, tariffs, etc.) have also been discussed to address urban–rural conflicts and find acceptable ways of equitable water sharing [3,84,85]. More recently, studies have emphasized on multi-level governance, multi-stakeholder engagement, multi-sectoral approach, and multi-disciplinary research [13,86]. The importance of stakeholder involvement is increasingly being recognized in reference to the transboundary scale of river basins and the varied policy preferences of urban–rural stakeholders [44]. By methodically reviewing a range of water governance studies, Daniell and Barreteau [86] highlighted specific bridging mechanisms for managing water conflicts such as institutional interplay (like legal reforms), co-management (like water-sharing agreements), and boundary organizations (like facilitators).

2.3. Significance of Benefit Sharing Measures

The increasing water transfer to urban areas—be it temporary, permanent, or outright—has certain negative impacts on the environment and other co-dependent sectors, like agriculture [76]. In that regard, the evolving idea of benefit sharing in terms of financial compensation, new infrastructure development and alternative water supplies, has demonstrated extreme potential for enhancing transboundary cooperation [26,48]. Over the last few decades, benefit sharing measures like Payment for Ecosystem Services (hereinafter referred to as PES) have emerged as a promising market mechanism that ideally complement the existing resource management practices. These measures are implemented through new institutions and frameworks, which bring together diverse stakeholders to collectively deliberate on mitigating the negative externalities [87–91].

PES schemes essentially require the ecosystem service users (like urban residents) to make voluntary payments, that are directed towards the service providers (like upstream farmers) for protecting, restoring, and conserving natural ecosystems (like forests and wetlands) [88]. This approach has also been emphasized in the United Nations World Water Development Report 2018 [39], to accelerate the uptake of nature-based solutions for water management. Although PES measures are still relatively new, they are increasingly being propagated as a governance instrument to enhance resource security and poverty alleviation [90]. A number of successful PES schemes have already been implemented in different parts of the world. Several such schemes driven by diverse actors, like governments, private sector, non-governmental organizations, etc., can also be detected in Asian countries like China, Japan, Indonesia, Vietnam, etc. [91]. To further understand the execution of benefit sharing measures at local level, the following subsection describes a good practice from Japan, which has a long history (more than 120 years [92]) of implementing PES schemes.

2.4. PES Schemes for Water Environment Conservation in Japan

Japan is a mountainous country with nearly 70% of the land covered by forests. Majority of these forest lands are privately owned and nearly 40% of these forests are man-made. The forestry sector was one of the most prominent industry in Japan after the World War II, but the situation has now totally changed. Due to the cheaper timber imports, declining profits, and ageing population, the country is faced with a serious challenge of forest management. As the upstream forest areas form an integral part of the water-source environment in Japan, the degrading forests also have implications on water conservation by watershed forests. To address these concerns, the local governments in Japan have implemented several PES schemes aimed at effective management of these privately owned forests [92,93]. Before discussing these schemes, it is important to first understand the water policy and governance frameworks in Japan.

Japan is a unitary state, which has three levels of government namely the national, prefectural (like states), and municipal (cities, towns, villages, and special wards). The prefectures (total 47) and municipalities form the two tiers of local administration system, which function within the basic framework set by national laws. At the national level, five different ministries (of the total 11) of the Japanese government are in charge of different water-related affairs like Water Supply (Ministry of Health, Labour and Welfare); Water Environment (Ministry of the Environment); River Control, Water Resource, & Sewage System (Ministry of Land, Infrastructure and Transport); Industrial Water (Ministry of Economy, Trade and Industry); and Agricultural Water (Ministry of Agriculture, and Forestry) [94,95].

Japan has a long history of dealing with issues related to water environment conservation (like water quality preservation and water efficiency), for which they have made significance advancements in terms of new regulations, economic measures, etc. Otsuka et al. [96] provided a historical overview of water environment conservation policies in Japan. The amendment of Japan's River Law in 1997 is recognized as a landmark in mainstreaming environmental conservation and public participation in river management. Later, the Omnibus Decentralization Act (2000) empowered the local governments and enhanced local autonomy. The Law for the Promotion of Nature Restoration (2002) and the Law on Special Measures for Lake Water Quality Preservation (2005) further provided a strong basis for local governments to preserve forestry and water resources through local taxation measures. Subsequently, in the backdrop of revenue shortages, several prefectures implemented their own forest and water-source environment conservation taxes in the early 2000s. With a key objective to promote cost sharing by all prefectural residents, these taxes are generally imposed as an added amount (or rate) to the prefectural resident's tax, which vary in different prefectures in terms of objective, design, distribution of tax burden, etc. Since 2003, more than 30 prefectures have introduced such environment conservation taxes. While most of them are centered on forests, the taxation policy of Kanagawa Prefecture has particularly focused on water-source conservation in upstream river basins [92,96,97].

2.4.1. Prefectural Inhabitant Tax for Water-Source Conservation in Kanagawa, Japan

Spread over an area of 2416 square kilometers (km), Kanagawa Prefecture is a part of the Greater Tokyo Area and has a population of more than nine million. Bulk of the water demands in Kanagawa (≈90%) are met through Sagami and Sakawa Rivers, both of which originate in the neighboring Yamanashi and Shizuoka Prefectures. While around 80% of the river catchment areas fall outside the prefecture boundaries, about 70% of the forest lands in these headwater areas are privately owned and have reportedly deteriorated over the years [98,99]. In the aftermath of policy reforms discussed in Section 2.4, a long-term plan was also laid out by Kanagawa Prefecture to conserve and restore the water-source areas, as it adopted the Basic Policy for Kanagawa Water Source Environment

Conservation and Restoration (2005–25) [100]. In reference to Fujita [101], the three key characteristics of Kanagawa's water taxation policy are summarized as follows:

1. Planning: The Prefectural government formulated a 'Five-Year Action Plan for Conservation and Restoration of Water Source Environment' in the year 2006, which listed 12 comprehensive initiatives (such as forestry conservation, groundwater protection, awareness raising) to be carried out under the Basic Policy. This plan listed out specific measures for engaging in water-source environment conservation during the first five years of the twenty-year period.
2. Taxation system: After a thorough investigation of water-source environment, it was estimated that additional costs of around 19 billion Japanese yen (JPY; around 3.8 billion JPY per fiscal year) would be required to implement the 12 defined programs during the first five years. To sustainably finance these programs, the Kanagawa prefectural inhabitant tax was increased by a fixed rate of 300 JPY per year, and the ratio of original tax was increased by 0.025% of their income. These tax rates are revised every five years to meet the estimate costs of implementing the defined action plans. However, the most notable point here is that the basis for calculation of tax amounts, the anticipated revenue and the planned usage of this tax is clearly demonstrated to the prefectural residents at the very beginning. To maintain complete transparency in the usage of this earmarked tax revenue, a new special account is established named 'Kanagawa Prefectural Government Account for Conservation and Restoration of Water Source Environment Programs', within which 'Kanagawa Prefectural Government Fund for Conservation and Restoration of Water Source Environment' is created.
3. Resident participation: The Prefectural government established a 'Prefectural Resident Council' in FY2007 to enhance the participation of prefectural residents in transparent utilization of funds. The council not only mainstreams the opinions of prefectural residents, but also evaluates and reviews the planned measures to conserve and restore water-source environments. The council also sets up an expert committee to verify the implications of proposed projects, which comprise experts, publicly recruited committee members, civil society, government officials, etc.

The success and efficacy of Kanagawa's water taxation policy could be realized through the fact that Kanagawa Prefecture in 2018 formulated the third phase of its 'Five-Year Action Plan for Conservation and Restoration of Water', with continued stakeholder engagement and transboundary cooperation [98]. The participatory approach of Kanagawa Prefecture has been recognized as an administrative reform at local level, due to the involvement of diverse stakeholders right from the policy formulation stage and the transparent utilization of funds. It should be noted that the policy was implemented only after a prolonged discussion (since the year 2000 [97]) with the citizens and municipalities on points like the funding schemes, taxpayer's ability to pay, and resident participation. The social consensus achieved through the deepening of residents understanding of the tax has also turned out to be a key reason behind the success of Kanagawa's approach.

3. Case Study Area—Nagpur, India

Nagpur—often called the 'Orange City'—is uniquely situated at the geographical center of India (location shown in Figure 1). Spread over an area of 217.56 square km with a population of 2.405 million (as per Census 2011), Nagpur is the 13th largest urban agglomeration in India, and the third largest city in Maharashtra State after Mumbai and Pune. Earlier, Nagpur was the capital of Central Province in mid-19th century before the states were reorganized in 1956. With a history of more than 300 years, Nagpur continues to be recognized as an important commercial and political center of Central India, mainly due to its strategic location and good connectivity with other parts of the country. The wider Nagpur Metropolitan Area (NMA; shown in Figure 1) was notified by the State Government on 23rd July 1999. Within the geographical spread of 3577.70 square km, NMA comprises 721 villages and 24 Census towns [102–105].

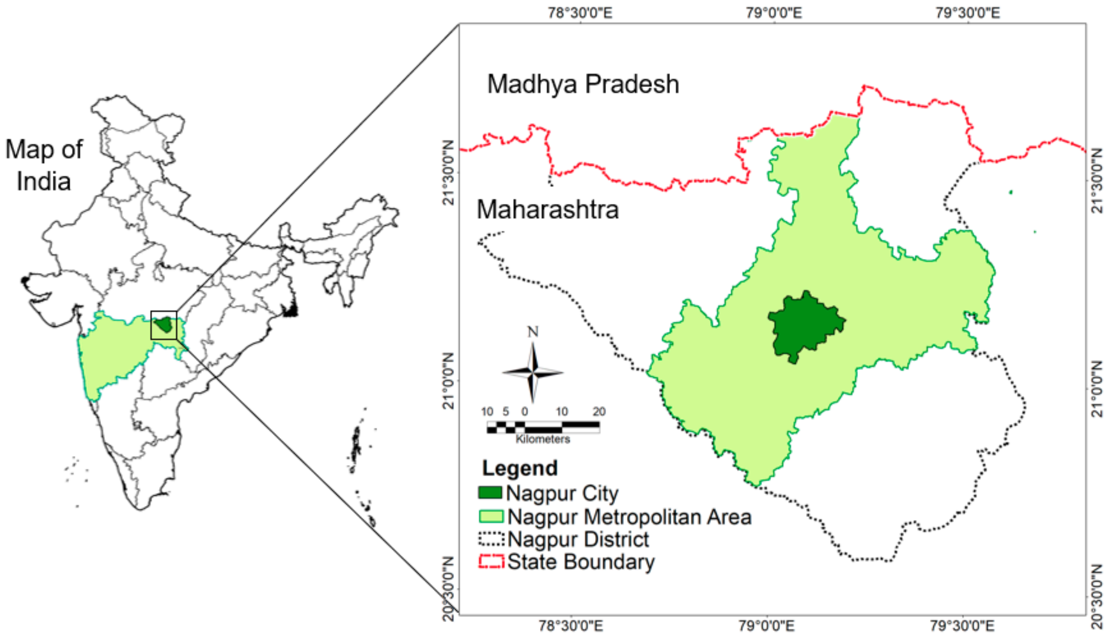

Figure 1. Location map of Nagpur City and Nagpur Metropolitan Area in India (source: the authors).

Nagpur region has a tropical savannah climate with dry conditions prevailing for most of the year. The peak temperatures, as high as 48 degree Celsius, are usually reached during the months of May/June, and the average annual rainfall is 1161.54 mm. Geomorphologically, NMA can be divided into two parts. The west portion of Nagpur City is occupied by the Deccan Traps formation, and the east portion is occupied by the metamorphic and crystalline series. Overall, NMA has an undulating plateau with natural slopes in two directions. The upper portion of NMA slopes from the north to southeast direction, while the lower portion slopes from the southwest to southeast direction. Along the natural slopes, NMA is drained by Kanhan and Pench Rivers in the center, by Wardha River in the west, and by Wainganga River in the east [102–105].

3.1. Water Supply in Nagpur City

The water supply in Nagpur City is managed by the Nagpur Municipal Corporation (NMC), an elected urban local body. NMC currently procures about 670 million liters per day (MLD) of water from a variety of sources (both surface and groundwater sources) [103]. While groundwater is marginally utilized (around 10 MLD [102]), the city's water demands are primarily met through three surface-water sources (refer to Figure 2) namely Gorewada Lake, Kanhan River and Pench Dam. In reference to earlier studies [102–106], the key characteristics of these surface-water sources are explained below:

1. Gorewada Lake: Developed in the year 1911, Gorewada Tank is one of the oldest water sources of Nagpur. It is situated at a distance of around 8 km from Nagpur City in the northwest direction and consists of an earthen bund across Pili River. The city annually receives an allocated quantity of 5.8 million cubic meters (MCM) (around 16 MLD) from Gorewada Lake [103]. Over the years, Gorewada Lake has become inadequate to meet the growing water demands in the city, as it could not be augmented due to site conditions. In the year 2019, the lake got dry for the first time in more than 100 years [60].
2. Kanhan River: First constructed in 1940, the Kanhan water-supply scheme was commissioned in four phases during the years 1940–70. Under this scheme, intake wells were developed along Kanhan River from which raw water is pumped to a treatment plant. Located at a distance of around 14 km from Nagpur City, Kanhan intake wells serve for around 25% of city's water demands. Nagpur presently receives an annual allocation of around 65.71 MCM (around

180 MLD) from Kanhan Intake wells [103]. In the recent years, the raw water availability in Kanhan River has declined due to the development of Kochi barrage in upstream areas [59,62], which has considerably affected the water supply in Nagpur City.

3. Pench Dam: Across the Pench River, Navegaon Khairy Dam (Pench Dam) was executed in the year 1976, by the State Irrigation Department, to utilize the tail races from hydropower project at Totladoh dam, developed near the state boundary with Madhya Pradesh (M.P.). Thereafter, multiple augmentation schemes (Pench I, II, III, and IV) were commissioned to enhance its capacity. Located at around 45 km away from Nagpur City, Pench Dam presently serves as the main source of water supply for the city. The city receives an annual allocation of 190 MCM (around 520 MLD) from the project, that is more than 70% of the total water supply to Nagpur City [103]. In the recent years, Nagpur City has experienced significant disruptions in water supply due to the declining water availability in Pench Dam [61–65].

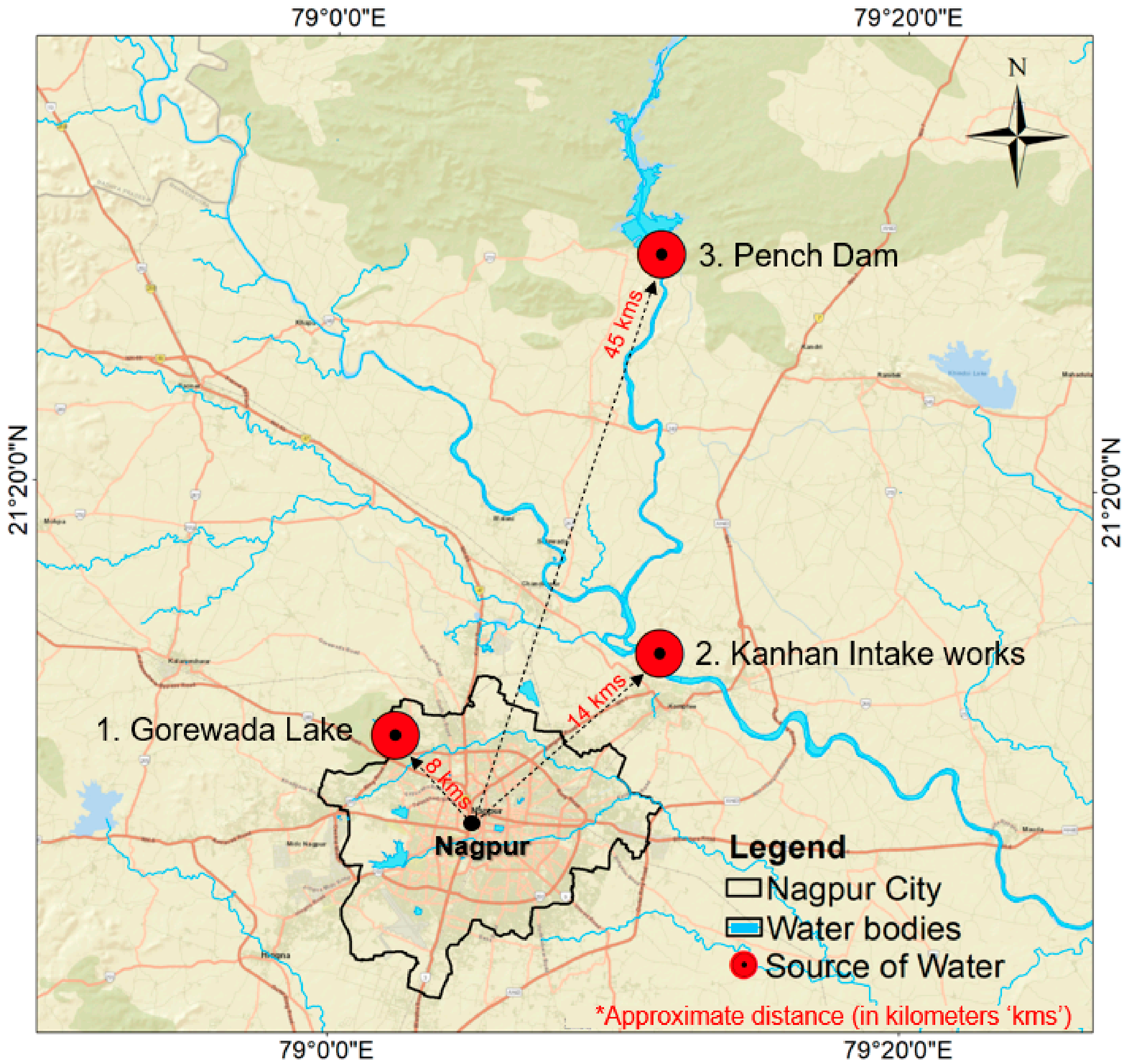

Figure 2. Location map of key surface-water sources for Nagpur City. Prepared by the authors; the background image was sourced from Esri, HERE, Gramin, USGS, Intermap, INCREMENT P, NR Can, Esri Japan, METI, Esri China (Hong Kong), Esri Korea (Thailand), NGCC, OpenStreetMap contributors, and the community.

Referring to the historical development of drinking-water resources for Nagpur City (shown in Table 1), the water supply is observed to have increased significantly over the years. To meet the rising demands of fast-growing urban population, a considerable proportion of water is now being fetched from the multipurpose Pench Dam, which itself receives water from the Totladoh Dam in the neighboring state of M.P. As per the NMC report (2011) [102], about 97 L per capita per day (lpcd) water is lost in transmission and distribution stages for every 200 lpcd of water supplied to the residents of Nagpur.

In the recent years, the declining water levels in Pench Dam have further raised an alarming water-stress situation for Nagpur City and the co-dependent rural areas. Apart from changing rainfall patterns, the media reports [56,58] have revealed that the development of Chaurai Dam in upstream areas of Pench River in M.P. State is one of the key reasons for ongoing water-stress situation. The haphazard infrastructure development in the recent years has also led to a loss of biodiversity and green cover, which severely affects the future water availability [107]. The anticipated population and economic growth of Nagpur City are expected to further strain the already stressed water resources.

Table 1. Historical development of drinking-water sources for Nagpur City.

Year	Population	Water Supply (in Million Liters Per Day)	LPCD Rate (Liters per Capita Per Day)	Surface-Water Sources
1921	145,000	16.50	114	Ambazari + Gorewada
1941	302,000	45.00	149	Ambazari + Gorewada + Kanhan
1961	644,000	80.00	124	Ambazari + Gorewada + Kanhan
1981	1,217,000	125.00	103	Gorewada + Kanhan
2001	2,150,000	370.00	172	Gorewada + Kanhan + Pench
2004	2,350,000	470.00	200	Gorewada + Kanhan + Pench
2011	2,447,000	651.00	266 (including water losses)	Gorewada + Kanhan + Pench

Data source: Deshkar [108] (p. 147).

4. Research Methods

Amongst the three key surface-water sources discussed in Section 3.1, this research mainly focusses on the multipurpose Pench Dam that serves as the main source of fresh water for Nagpur City and also serves for other purposes, including irrigation in the Pench command areas. While Nagpur City receives priority water allocation from Pench Dam to meet their growing demands, this research seeks to understand its cross-sectoral and transboundary implications for the co-dependent rural areas. With an objective to generate grounded evidence for substantiating the ongoing urban–rural water conflicts in NMA, a combination of qualitative (review of official reports) and quantitative (secondary data analysis) research methods were adopted for this study.

To comprehend the history of the Pench Project, the authors first studied the Performance Evaluation Study of Pench Irrigation Project, which was conducted by the Central Water Commission (CWC), Government of India in 2001 [109]. This report is an official document, and the authors collected it from the State Irrigation Department, Government of Maharashtra [110]. Based on the CWC report, the authors underline the initially planned water allocation from the Pench Project and discuss it in reference to the present scenario. The study of these historical processes is mainly intended to establish a wider context for this research.

Further, three specific sets of secondary data were collected from the State Irrigation Department [110], to understand the cross-sectoral and transboundary water-related issues in NMA:

1. Annual water utilization trends (1990 to 2019) from the Pench Project, for the purposes of Irrigation, NMC (urban domestic), and industries (thermal power stations).
2. Total irrigated area, annually (2001 to 2019), from the Pench Project, in different seasons (Kharif, Rabi, and Zaid (hot weather)).

3. Total irrigated area, annually (2001 to 2019), from the Pench Project, using different irrigation methods (flow, lift, and well).

In reference to the history of the Pench Project, the annual water utilization trends and the total irrigated area, annually, from the Pench Project, have been studied to understand the cross-sectoral concerns due to the declining water availability. Further, the transboundary water-related concerns are investigated in relation to the overall groundwater use for irrigation. The study of total irrigated area from the Pench Project, using different irrigation methods (flow, lift, and well), is meant to understand this issue, as surface and groundwater are normally considered to be substitutes in agriculture production. This is in reference to a similar study conducted by Celio et al. [34], for the case of Hyderabad City, India.

5. Results

5.1. Historical Timeline of Pench Project

The Pench (Hydropower) Project is an interstate project between M.P. and Maharashtra States of India. The history of this project (illustrated in Figure 3) dates back to 1922 when Mr. J.W. Mears suggested a scheme on Pench River—a tributary of Kanhan River, in Godavari Basin—in their report 'Water Power Resources of India' [111]. The systematic planning of the scheme was undertaken during 1954–55 by the erstwhile Central Water and Power Commission (CW&PC), now CWC. At that time, the entire catchment area of this project came under the erstwhile M.P. State, before the states were reorganized in 1956. After the formation of Maharashtra State in 1960, the administrative position changed and the whole scheme was recast to ensure equitable distribution and utilization of Pench River's water. In lines to that, Totladoh Dam was constructed for hydropower generation as a joint venture between Maharashtra and M.P. The catchment area of Totladoh now lies in M.P., and the dam and downstream areas come under Maharashtra (as shown in Figure 4). To mutually share the benefits from the Pench Project, an agreement was reached between these two states during March 1964 (summarized in Figure 5). As per the agreement, the hydropower generated from Totladoh is shared in ratio of 2:1 by M.P. and Maharashtra, respectively. However, the state of Maharashtra utilizes the tailrace releases from Totladoh fully for its own purposes [109,112].

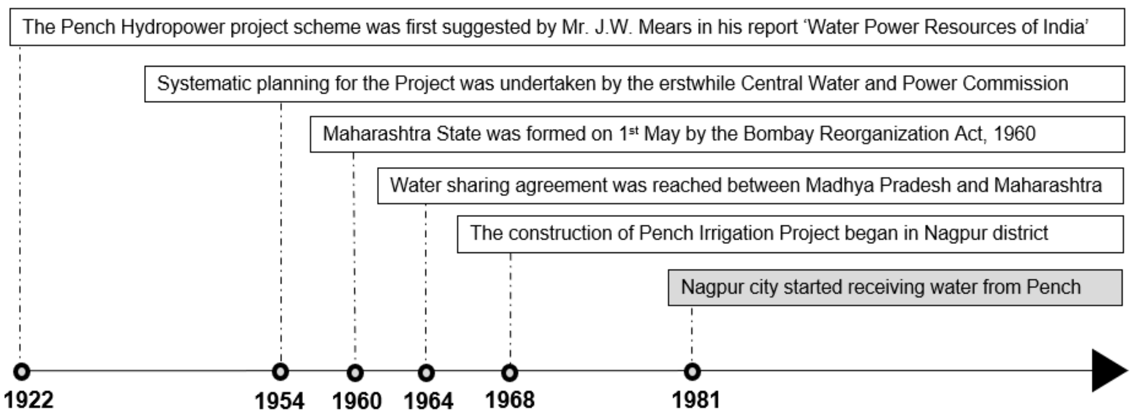

Figure 3. Historical timeline of the Pench Project. Information source: Reference [109].

To effectively utilize the tailrace releases from Totladoh Dam, Pench Irrigation Project (PIP) was implemented in Nagpur, Maharashtra. In addition to Totladoh, PIP comprises two other dams, namely Pench Dam and Khindsi Tank (location of all three dams shown in Figure 4). The Pench Dam is constructed across the Pench River at about 23 km downstream of Totladoh, near the village Navegaon Khairy. It has lined canals on both the (left and right) riverbanks to irrigate around 104,476 hectares (1044.76 square km) of land (command area), which benefit around 406 villages in Nagpur and Bhandara districts. The second dam is Khindsi Tank—constructed in 1913 near Ramtek on River

Sur—which feeds to the Pench canals. The storage capacities of the three dams under the PIP are as follows: (1) Totladoh, 1041 MCM; (2) Pench, 180 MCM; and (3) Khindsi, 104.26 MCM [109,113].

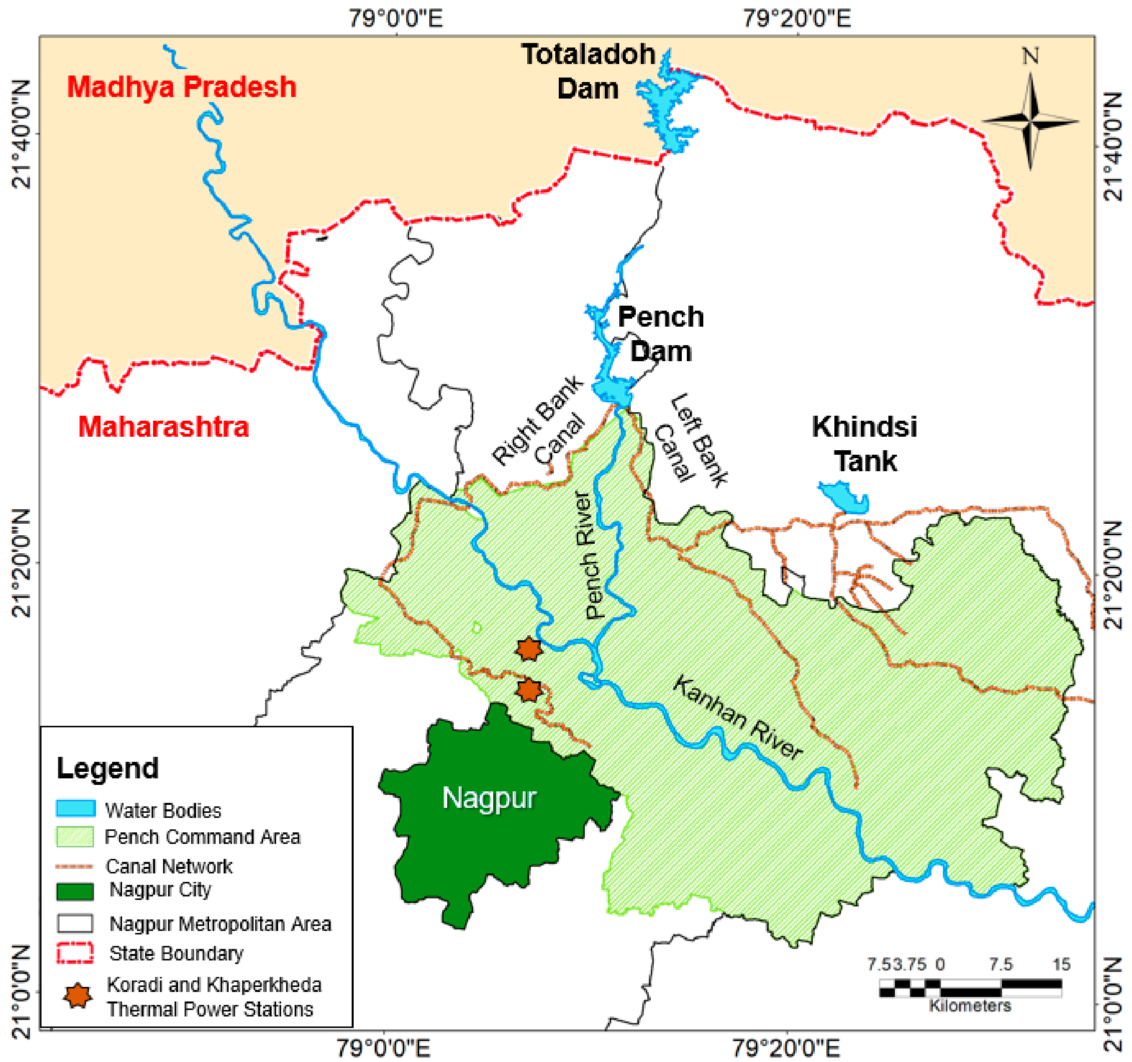

Figure 4. Spatial description of Pench Irrigation Project in Nagpur Metropolitan Area (NMA). Prepared by the authors, based on secondary data collected from the State Irrigation Department [110]. Only the command area within NMA boundary is highlighted here, but it also extends farther.

5.2. Increased Water Transfer from Pench Irrigation Project to Nagpur City

Table 2 highlights the initially determined water allocation planning by the Government of Maharashtra for the estimated water availability of 965 MCM at PIP (refer to Figure 5). It should be noted that the water allocation for NMC was made during the planning stage itself. Since 1981, NMC has been receiving an annual allocation of 112 MCM from PIP through the Right Bank Canal (RBC). However, NMC started drawing more water than the allotted quantity from 1997–98 to meet the demands of growing population in Nagpur City. Considering the request by NMC, the State Irrigation Department (vide letter dated 19th August 2000) authorized NMC for an additional 78 MCM of water from the tail end of RBC. This additional water allocation to Nagpur City had widespread implications for irrigation in rural areas, as area under irrigation reduced by 8658 hectares (86.58 square km). Nevertheless, it was permitted as a temporary allocation till the year 2005. By that time NMC was supposed to make separate arrangements to meet their growing water demands [109].

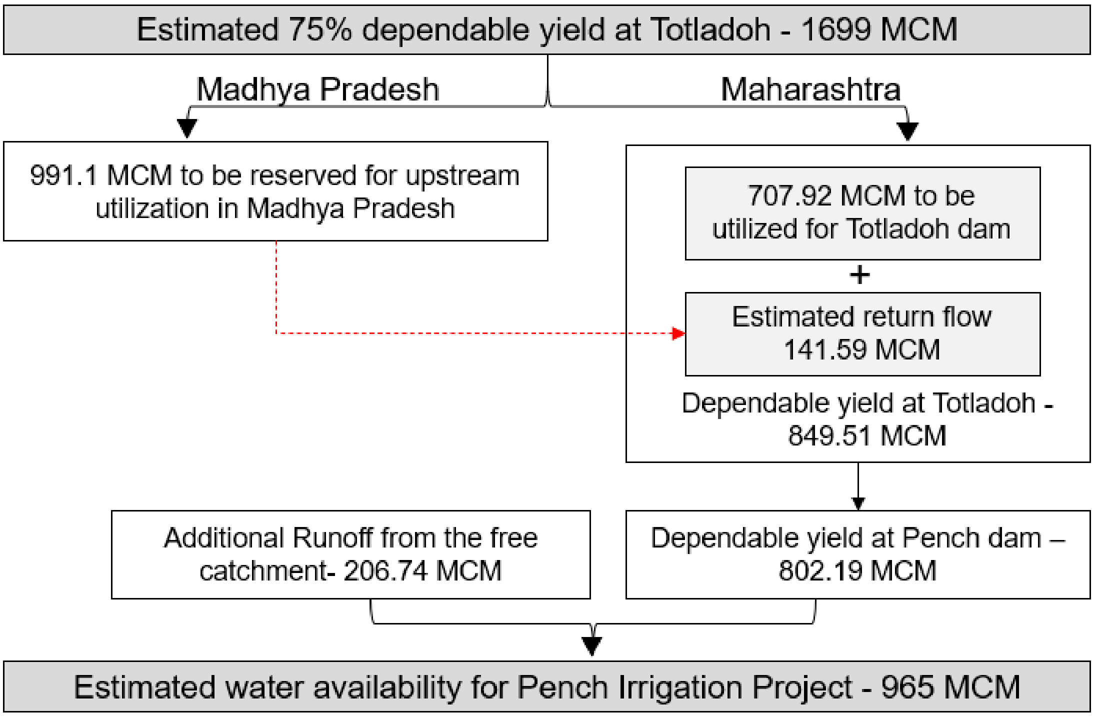

Figure 5. Summary of Pench water-sharing agreement (information source: Reference [109]). MCM = million cubic meters.

Table 2. Water-allocation planning for the Pench Irrigation Project, 1996.

S.No.	Description of Water User	Allocation
1	Irrigation	689
2	Nagpur Municipal Corporation	112
3	Koradi Thermal Power Station	67
4	Khaperkheda Thermal Power Station	60
5	Fisheries Department	2
6	Sunflag Industries, Bhandara	2
7	Evaporation losses	33
	Total (in million cubic meters (MCM))	965

Data source: Reference [109] (p. 29).

Two decades later, today, the additional supply of 78 MCM is still continuing, and the city has now become fundamentally dependent on Pench Dam for its water supply. In the same regard, a Public Interest Litigation (PIL) was also recently filed in Nagpur Bench of Honorable High Court of Bombay on 3rd July 2017 [113]. However, it was ruled that the additional reservation of 78 MCM could not be set aside, as per section 31(B) of Maharashtra Water Resources Regulatory Authority (MWRRA) Amendment and Continuance Act [114]. Through this case, an urgent need for developing alternate water sources was realized, and NMC was directed to implement a long-term strategy for water management.

5.3. Cross-Sectoral Implications of Increased Water Transfer to Nagpur City

The 100% stacked column chart shown in Figure 6 is quite revealing in several ways. Firstly, it should be noted that the annual water available through Pench Project has been highly fluctuating. Against the estimated water availability of 965 MCM (refer to Figure 5), the actual water availability is seen to have varied from a maximum of 1307.87 MCM (year 1997–98) to a minimum of 448.01 MCM (year 2001–02) in the past three decades. Nevertheless, for most of these years, PIP has been receiving surplus water (>965 MCM).

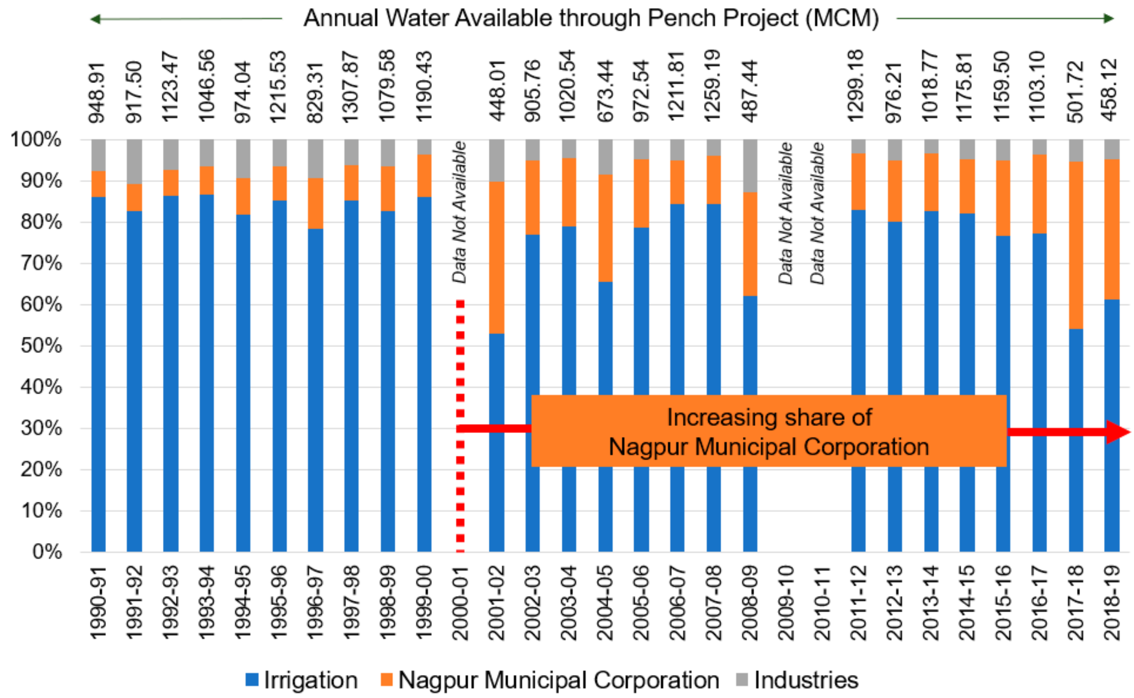

Figure 6. Annual water-utilization trends from the Pench Irrigation Project (1990 to 2019). Information source: References [109,110].

Further, Figure 6 also shows the annual water utilization trends of PIP for three key sectors of Irrigation, Urban domestic (NMC) and Industries (Koradi and Khaperkheda Thermal Power stations (TPSs)). Evidently, the water allocation for NMC has increased after the year 2000, which is likely due to the additional water allocation of 78 MCM sanctioned by the Government of Maharashtra in the same year (refer to previous Section 5.2). Since then, NMC has received a considerable proportion of water from Pench Dam, even during the water deficit years. Although the priority water allocation to NMC is in lines with the priority list set by the State [115] and National Water Policy [116], the water availability for other co-dependent sectors (mainly irrigation) is directly affected as Pench Dam is a shared water resource.

According to the guidelines of State Government [117] (p. 2), the sectoral water allocation at project level for domestic, industry and irrigation sectors is set as 15%, 10%, and 75% respectively. Against the set benchmarks, considerable fluctuations have also been observed in the sectoral water allocation from the Pench Project (as seen from Figure 6). Between 1990 and 2019, the percentage water allocation for NMC (urban domestic) varied from a minimum of 6.21% (1992–93) to as high as 40.51% (2017–18). For Irrigation sector, the highest allocation of 86.75% was during the year 1993–94, and the lowest was 52.90% during 2001–02, followed by 54.23% during 2017–18. The significant variations in water allocation from PIP mainly highlight the growing concerns of cross-sectoral water conflicts.

The stacked column chart shown in Figure 7 illustrates the annual irrigated area (from 2000 to 2019) under the Pench command areas. The chart shows the annual irrigated area under three cropping seasons, namely Kharif (July to October), Rabi (October to March), and Zaid 'hot weather—HW' season (March to June). Kharif and Rabi are two main agricultural seasons in India, and the third (HW or Zaid) is a short cropping season during summer months. It should be noted that the crops grown during Kharif season are entirely dependent on monsoon rains while those in Rabi and HW season mainly depend on timely irrigation [118].

Apparent from Figure 7, the annual irrigated area has increased over the years, which is in lines with the phase wise augmentation of the Pench Project (explained in Section 3.1). The initially estimated maximum area of irrigation through PIP (104,476 hectares; refer to Section 5.1) was reached in the year

2013–14. Even then, the annual irrigated area through PIP has kept on increasing till 2016–17, which is likely due to the surplus water availability during those years (as seen in Figure 6).

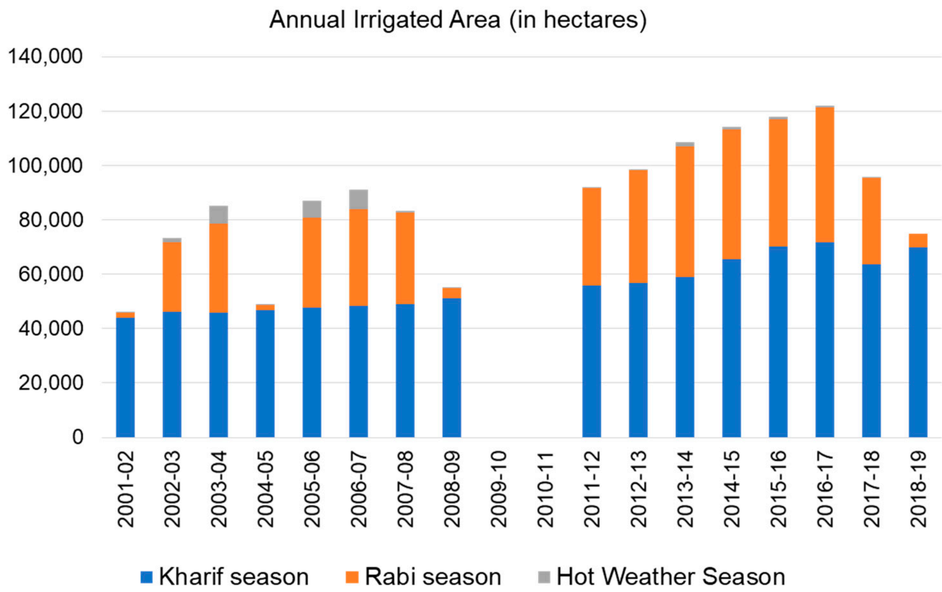

Figure 7. Annual irrigated area (season-wise) from the Pench Project (2001–19). Information source: Reference [110].

The key point to be noted here is that there have been significant fluctuations in irrigated area during the years of 2001–02, 2004–05, 2008–09, and 2018–19, mainly in Rabi season. During the same years, NMC has received a substantial allocation of water (36.94% in 2001–02; 25.94% in 2004–05; 25.21% in 2008–09; and 34.20% in 2018–19) from the PIP (refer to Figure 6). Based on this observation, it is clear that there is a close association between water supply to NMC and irrigation in the Pench command areas. Although it is difficult to estimate the precise impacts of increasing water supply to NMC on agricultural productivity. However, even a marginal increase in water supply to NMC is bound to have cross-sectoral implications for other co-dependent sectors, as the Pench Project serves as a shared water resource. Since agriculture is the overall largest consumer of water from the Pench Project, the declining water availability and the increasing water transfer to Nagpur City indirectly affects the rural areas that fall under Pench command area.

5.4. Transboundary Implications of Increased Water Transfer to Nagpur City

Figure 8 highlights the annual irrigated area (from 2001 to 2019), under the Pench Project, in the form of a 100% stacked column chart. This chart shows the percentage of annual irrigated area in reference to three specific methods of irrigation, namely flow (gravity flow), lift (lift from canal), and well (irrigation through wells). It is intended to examine the trends of surface and groundwater use in overall agricultural system under the Pench command area.

It can be seen from Figure 8 that the magnitude of groundwater use (through wells) for irrigation has gradually increased in the command areas of Pench, particularly in the recent years. There is limited information to validate if the increased groundwater use for irrigation is mainly due to the declining availability of surface water. However, based on the historical trends highlighted through Figures 6–8, it is clear there is a certain level of association between them. This finding is also in agreement with the study conducted by Celio et al. [34] which underlined that surface and groundwater sources are direct substitutes for irrigation.

As per the recent estimation of Central Ground Water Board (CGWB) and Groundwater Survey and Development Agency (GSDA) in 2013, the overall stage of groundwater development in NMA (including the Pench command area) falls under the safe category [119]. Still, the excessive utilization of groundwater resources cannot be seen as a long-term strategy for mitigating the urban–rural conflicts, mainly as groundwater resources are de facto a private resource. Even in the National Water Policy of India [116], it has been underlined that groundwater resources are perceived as an individual property. Due to the decentralized access to groundwater resources, they are often exploited inequitably and the increasing groundwater use may not be sustainable in long-term.

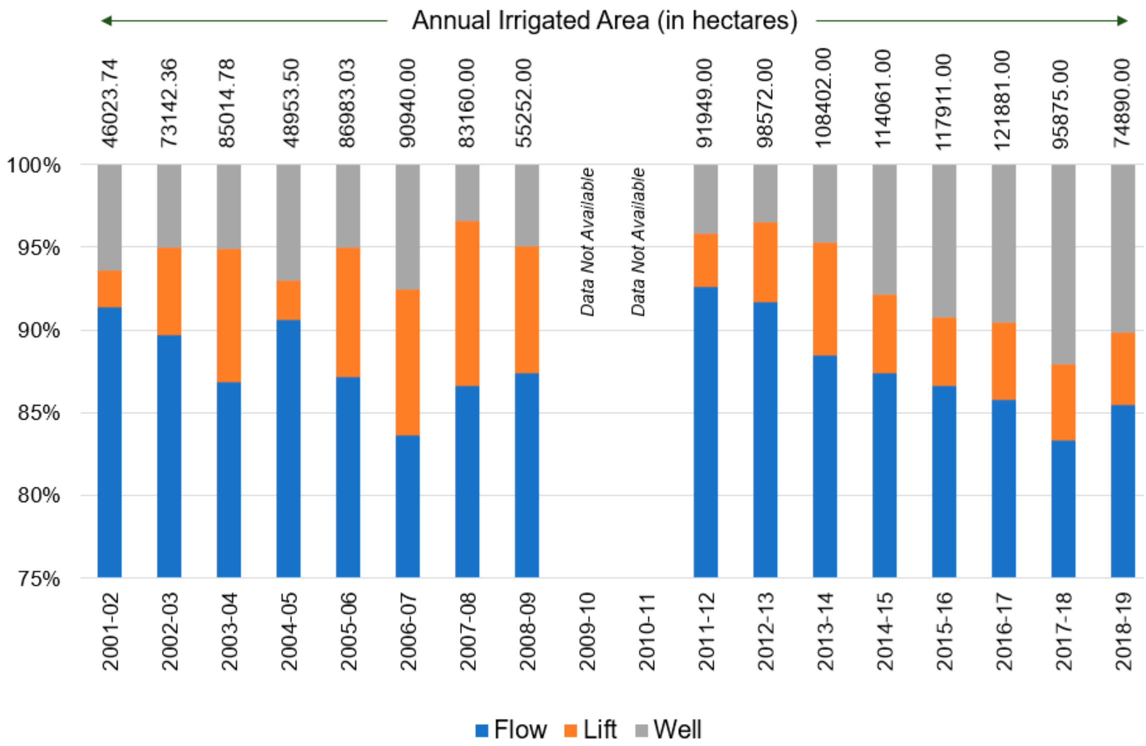

Figure 8. Irrigation trends in Pench command area, based on different irrigation methods. Information source: Reference [110].

6. Discussion

Water is a state subject in India, and the state governments address all the water-related affairs through various ministries and departments [120,121]. The institutional structure for water governance at various administrative levels in Maharashtra State is explained in Figure 9. At the state level, there are two key agencies namely the Water Supply and Sanitation Department (WSSD) and the Water Resources Department (WRD; formerly Irrigation Department). While WSSD is responsible for formulating and implementing policies for regional water-supply schemes in both urban and rural areas, WRD is responsible for planning and development of irrigation facilities in the state. Further, several other agencies are responsible for planning, design, execution, and maintenance of water-supply schemes at different governance levels (river basin, district, block, city, village, etc.) in Maharashtra State.

As briefly explained in Section 3.1, the water supply in Nagpur City is managed by the NMC. It is presently being operated under a Public–Private Partnership (PPP) contract with a private agency called 'Orange City Water Pvt. Ltd.' [104]. The annual water allocation for NMC from the Pench Project is determined by the Vidarbha Irrigation Development Corporation (VIDC; river basin agency), as per the norms set by MWRRA [57]. VIDC serves for strengthening multi-sector planning and management of water resources at river basin level in Maharashtra. However, the catchment areas of the Pench Project lie in the neighboring M.P. State (as discussed in Section 5.1). Herein, the authors intend to highlight that connecting river basin management with water resource management at local level continues to be a critical challenge as river basin boundaries do not comply with the administrative boundaries. Earlier studies on urban water management in India [121–123] have also underlined the critical governance challenges that occur due to multiple agencies in terms of inter-departmental coordination, administrative overlaps, etc.

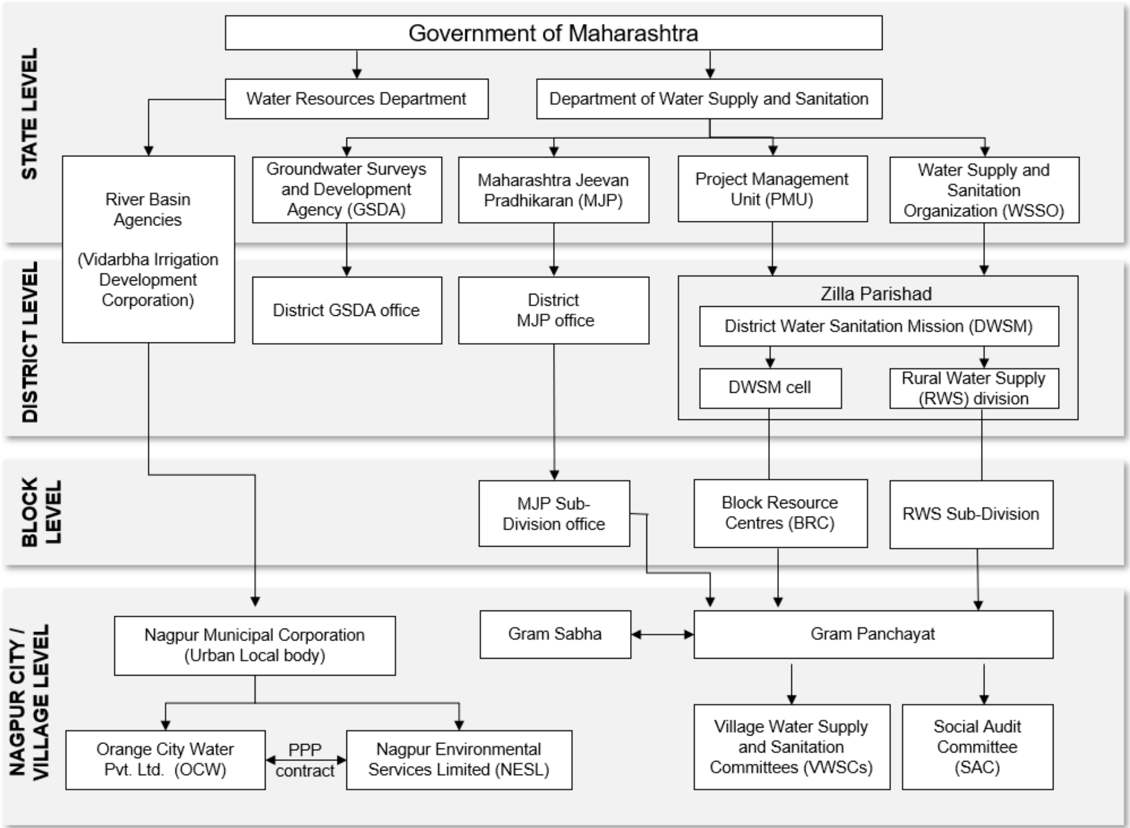

Figure 9. Institutional structure for water governance in Maharashtra State. Prepared by the authors, in reference to earlier studies [104,120]. The figure only provides a generalized understanding of water governance in Maharashtra. Additionally, there are several other agencies at different governance levels.

The evidence from this study suggests that the water inflow to Pench Dam has become more variable over the years and has lately diminished. Consequently, Nagpur City has in recent times experienced situations of direct water stress, despite the increased transfer of water and priority allocation from the Pench Project (explained in Section 5). It has also been noticed that the water supply to Nagpur City has reduced—now and then—to amounts less than the urban quota, while the irrigation perimeter has kept on increasing even beyond the initially planned area (refer to Section 5.3). In due consideration to these cross-sectoral and transboundary links with the co-dependent rural areas, the city government needs to develop a long-term strategy for water resource management.

Building on the literature review (Section 2) and the research findings (Section 5), the study suggests two specific strategies to enhance water resource management in NMA. To bridge the existing science-policy gaps and to ease the policy integration of research findings, the suggested measures have also been linked with the relevant sections of existing policy frameworks.

6.1. Implementing Benefit Sharing Measures at Policy and Governance Levels

As depicted in Figure 9, there are multiple agencies that work for water resource management at regional level in NMA. However, at the city level, NMC is the key agency responsible for the provision of civic amenities and comprehensive development. In face of growing water demands in the city and declining water availability, NMC needs to take urgent measures to enhance water use efficiency, reduce distribution losses and develop alternate sources of water supply (issues highlighted in Section 3). At the same time, the city also needs to avoid any cross-sectoral and transboundary implications in terms of decline in irrigated area and increase in groundwater use for agriculture (as revealed in Sections 5.3 and 5.4). Through the study results, it is seen that the urban domestic demands are closely interlinked with the irrigation in Pench command areas. During the water deficit years, the water demands in Nagpur City are often met at the cost of irrigation needs, as they depend on shared water source of Pench. To holistically address the emerging direct as well as indirect water-stress concerns at regional level, the city government needs to take into account the water–energy–food nexus to achieve sustainable urban development in long-term (also emphasized in Section 1).

In view of the largescale investments required for enhancing water resource management (like for infrastructure development, technology advancements, etc.), the policy makers need to consider the implementation of incentive-based governance approaches for stimulating the principles of co-management in NMA (also emphasized by Kilimani et al. [85]). Since the Pench Project is an interstate arrangement, the implementation of any benefit sharing measures in case of Nagpur can serve as a win–win solution not only at the regional level, but also at the state level. Markedly, the PES schemes have been receiving increasing prominence in the Indian context [89], mainly as the 73rd and 74th Constitutional Amendment Acts [124,125] have assigned devolved powers and functions to local government levels (like Municipal Corporations and Village Councils).

Several committees and associations for surface and groundwater management are already existing in NMA like the Watershed Water Resources Committees (established under Maharashtra Groundwater Development and Management Act 2009 [126]) and Water User Associations (WUAs; established under the Maharashtra Management of Irrigation Systems by Farmers Act 2005 [127]). However, even with the established institutions at various governance levels, addressing the rising growing water conflicts at the urban–rural interface is a challenge. Pfaff et al. [128] underlined that the implementation and sustenance of PES agreements incur significant costs, including the time required for consensus building and platform development.

In that regard, several lessons could be derived from the good practice of Kanagawa Prefecture (discussed in Section 2.4.1). Like the case of Kanagawa, the water demands in Nagpur are largely met through surface-water sources, the catchment areas of which fall beyond the state boundaries. Although water governance structures in Kanagawa (Japan) are different from those in India, but three key lessons could be derived for implementing any potential scheme in context of NMA:

1. Planning: To achieve transboundary cooperation for collective water management, emphasis should be put on establishment of benefit sharing agreements between the key stakeholder groups like NMC, TPSs, WUAs, and other agencies, depending on the scale of consideration, like regional level, district level, or state level. With an agreed long-term strategy, an action plan should be developed to achieve sustainable water resource management at regional level.
2. Taxation system: Based on the estimated costs for implementing the defined projects, the possibilities of additional water tax or incentivization measures need to be explored by NMC, as it has the power to take decisions regarding consumer level pricing and taxation at city level. Based on a thorough needs assessment study at regional level and the assessment of urban consumer's 'Willingness to Pay', a feasible water taxation policy needs to be developed.
3. Resident Participation: Needless to say, it will be important to ensure the social acceptance of any such intervention, as these agreements can arise voluntarily if the service providers and users feel their merits [128]. To achieve that, more emphasis needs to be put on raising community awareness about the intensifying water scarcity and escalating pressures on water resources in NMA. An agreed monitoring mechanism for utilization of collected funds by varying stakeholder groups—like in the case of Kanagawa (refer to Section 2.4.1)—will go a long way to ensure transparency and inclusiveness.

6.2. Enabling Multi-Stakeholder Engagement for Integrated Water-Resource Management

Institutional interplay is for long recognized as a critical governance challenge for integrated management of water resources (as discussed in Section 2.2). In the case of NMA also, there are several agencies responsible for water resource management across different administrative scales. There are also several co-dependent sectors like irrigation, industry, fisheries, hydropower, etc. (refer to Table 2), that rely on the limited stock of water resources in the Pench Project. Although the water allocation is currently done as per the directions of state and national policies, the declining water availability often leads to cross-sectoral and transboundary water conflicts in NMA (revealed in Sections 5.3 and 5.4). To address these concerns, there is a genuine need for inclusive institutional structures or multi-stakeholder platforms in place. Even for the successful implementation of any benefit sharing measure in NMA, it will be important to ensure that the varying concerns and interests of the wide-ranging water users are taken into consideration and any potential conflicts are avoided.

In that respect, the Section 6.1 of the Maharashtra State Water Policy 2019 [115] recognizes that conflicts amongst inter-sectoral, inter-regional, and upstream–downstream water users are increasing at the basin level due to the growing water supply–demand imbalances. To address these issues, the policy has also emphasized on the importance of stakeholder engagement for water conservation, drought mitigation, etc. The importance of social consensus and broader partnerships is also recognized from the good practice of Kanagawa Prefecture, which builds on the principles of multi-stakeholder engagement and transboundary cooperation.

For the case of Nagpur, the study acknowledges that significant steps have already been taken to achieve holistic development in form of City Development Forum [129], Inter-City Forum [130], etc. However, there is a need for further strengthening such initiatives and widening their scope to regional level concerns. Likewise, considerable initiatives have also been taken by other government authorities for water conservation and management in rural areas (e.g., Jalyukt Shivar Abhiyan [131]). However, there is a need for synchronization between different urban–rural approaches to address these issues at river basin scale. To achieve that, the presence of any boundary organization (emphasized in Section 2.2) or committee will not only serve for inter-departmental knowledge sharing but will also pave the way for informed decision making at regional level.

7. Conclusions

This study set out with the aim to investigate the conflicts of water use through the Pench Project, in NMA, India. Based on the review of official documents and secondary data analysis, this study produced reliable scientific evidence to substantiate the ongoing water conflicts between urban and rural areas in NMA. Important insights into the history of the Pench Project were provided, before highlighting the changing trends of water utilization for different purposes, including urban domestic, industry, and agriculture. While the water availability in the Pench Project is subjected to changing climate and upstream developments in the neighboring M.P. State, the increased transfer of fresh water to Nagpur City is found to be disproportionately affecting the co-dependent rural areas, especially during the water-deficit years. Through a descriptive analysis of collected secondary data, the study uncovered the transboundary implications on rural areas in terms of periodic decline in irrigated area and the increasing use of groundwater for irrigation. Although the authors could not establish the precise statistical links due to data limitations, these impacts are inferred to be a likely consequence of declining surface-water availability in the Pench Project.

In reference to the projected economic growth of Nagpur City, the water demands are expected to further grow at a rapid rate. This will likely worsen the ongoing urban–rural conflicts, unless any concrete measures are taken to enhance transboundary cooperation. In view of the established urban–rural water linkages in NMA, the study has emphasized implementing benefit-sharing measures between concerned actors and to stimulate collective action for water-resource management. Referring to the successful case of Kanagawa (Japan), the authors have also highlighted the key lessons for implementing PES schemes and for enabling multi-stakeholder engagement. Most importantly, the authors have linked the suggested governance measures with relevant acts and policies to pave the way for policy integration of the research findings. It is therefore hoped that this study will serve as the basis for policy reforms in Nagpur. Although this research has focused on a specific case of

Nagpur, the derived lessons also have broader applicability in Indian context, wherein most of the fast growing cities are experiencing a water-stress situation.

Thus far, the authors have addressed the key research questions defined at the beginning of this study. However, the readers should bear in mind that this research is subjected to certain limitations. Firstly, the current research is largely based on the review of official reports and secondary data analysis. However, there is abundant room for further progress in terms of field surveys and statistical analysis to further substantiate the research findings, which falls into the future scope of study. Secondly, this research has examined the urban–rural water conflicts only in context of PIP in NMA. However, there are many other small and medium reservoirs, which serve for meeting the water demands in NMA. To execute a benefit sharing mechanism at regional level, there is also a need for broader consideration of upstream–downstream areas and the range of water users across different sectors. Further research also needs to be conducted to determine a feasible water-taxation policy and a transparent monitoring system for its wider acceptance; however, it lies beyond the scope of this study.

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