Multiobjective Optimization for Optimal Water Resource Allocation

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Abstract

This work investigates the use of multiobjective optimization (MOO) in the distribution of water resources, a crucial problem made worse by rising demand brought on by population expansion, industrialization, and climate change. Conventional unidimensional methods frequently fall short in considering the intricacies of conflicting water requirements in several domains, including domestic consumption, industry, agriculture, and environmental conservation. By striking a balance between these competing goals, MOO provides a more complete solution to guarantee fair, effective, and sustainable water distribution.

A case study of the Chotanagpur Plateau area shows how MOO might be used practically to solve problems with water allocation. The study demonstrates how MOO might lessen resource conflicts and advance sustainability in water-scarce settings by optimizing water allocation across home consumption, industry, agricultural, and ecological needs.

Finally, MOO offers a strong framework for the sustainable management of water resources in an increasingly uncertain future, balancing the interests of the social, economic, and environmental spheres.

Keywords— Optimization, Hydrology, Multiobjective , Chotanagpur Plateau, Water Resource

1 Introduction

Water is one of the most critical resources for human survival, economic development, and environmental sustainability. As populations grow and economies expand, the demand for water increases, exacerbating the challenges related to its distribution, management, and conservation. Competing demands from agriculture, industry, domestic use, and ecosystem maintenance have intensified the pressure on water resource systems, making efficient allocation a critical priority [128, 4, 113, 118, 76, 119, 32, 24, 39]. To address these challenges, multiobjective optimization (MOO) has emerged as a powerful approach for balancing competing objectives, ensuring optimal water resource allocation while considering economic, social, and environmental dimensions [108, 88, 53, 30, 91, 133, 36, 72, 100, 59].

In this paper, we explore the application of multiobjective optimization for water resource allocation, examining the complexity of balancing diverse and often conflicting goals in water distribution systems. The goal is to provide an optimal allocation strategy that meets the demands of various stakeholders, respects environmental limits, and accounts for future uncertainties like climate change, technological advancements, and economic fluctuations.

1.1 Background and Motivation

Water resource allocation typically involves trade-offs between multiple conflicting objectives, such as maximizing water supply reliability, minimizing costs, ensuring equitable access, and preserving ecosystems [31, 66, 105, 92, 135, 138, 81, 65, 108, 23]. Traditional optimization techniques, which often rely on single-objective frameworks, fail to capture the complexity of these interrelated and conflicting priorities. For instance, prioritizing agricultural water use may reduce the availability of water for urban areas or disrupt the ecological balance in a river system.

The need for multiobjective optimization arises from the inherent conflicts and complexities within water resource management. The classical approach of formulating the water allocation problem as a single-objective optimization, where the primary goal is to minimize or maximize a single objective (such as minimizing water shortage or maximizing profit), is often inadequate [9, 84, 18, 95, 101, 82, 75, 83, 26, 37]. Multiobjective optimization allows for a more holistic approach by simultaneously addressing various objectives that are equally important to different stakeholders. This technique enables decision-makers to evaluate trade-offs and generate a set of optimal solutions, commonly referred to as Pareto-optimal solutions, where no single objective can be improved without compromising another [134, 20, 10, 97, 33, 58, 34, 71, 69, 16].

Moreover, the increasing variability in water availability due to climate change further complicates the water resource allocation problem. Frequent droughts, unpredictable rainfall patterns, and extreme weather events place additional stress on water distribution systems. The application of multiobjective optimization can help develop more robust and adaptive allocation strategies that account for such uncertainties, ensuring water security and sustainability in the face of changing climatic conditions [61, 27, 6, 108, 82, 94, 139, 137, 45, 78].

1.2 Water Resource Allocation: A Multiobjective Problem

Water resource allocation involves managing the supply and demand of water across different sectors, including agriculture, urban consumption, industry, and environmental flows. Each sector has its own set of objectives and constraints [98, 74, 21, 108, 35, 89, 80, 77, 129, 7]. For example, farmers may prioritize water availability for irrigation to maximize crop yields, while urban areas may seek to ensure a consistent water supply for domestic consumption. Additionally, environmentalists advocate for maintaining sufficient water flows to preserve aquatic ecosystems, which are often in conflict with human water consumption needs.

These diverse and competing demands highlight the necessity for a multiobjective approach. MOO enables decision-makers to incorporate a variety of objectives, such as:

- **Maximizing Water Use Efficiency**: Efficient use of water in agriculture, industry, and urban areas is essential to reduce wastage and make better use of the available resource.

- **Ensuring Equitable Water Distribution**: Fair distribution of water resources across different sectors and regions, particularly between urban and rural areas, is critical to avoid socio-economic disparities.
- **Minimizing Costs**: Both the operational costs of water supply systems and the economic costs related to water shortages need to be minimized.
- **Sustaining Ecosystems**: Environmental considerations, such as maintaining minimum river flows to support aquatic life and ecosystems, are vital for biodiversity and long-term ecological balance.
- **Ensuring Water Supply Reliability**: Reliable water supply systems are critical to prevent disruptions in water availability due to seasonal variations or infrastructure failures.

1.3 Multiobjective Optimization Methods in Water Resource Allocation

These algorithms, such as the Non-dominated Sorting Genetic Algorithm II (NSGA-II)[28] or Multiobjective Particle Swarm Optimization (MOPSO) [96], use population-based approaches to generate a diverse set of solutions. They are particularly useful for complex, nonlinear water resource allocation problems, as they can explore a wide solution space and handle multiple constraints effectively.

1.4 Application of MOO in Water Resource Allocation

In practical applications, MOO has been successfully implemented in various case studies of water resource allocation. For instance, in river basin management, MOO has been used to balance water distribution among agricultural, urban, and ecological users while considering seasonal fluctuations and environmental constraints. In transboundary water management, MOO helps resolve conflicts between neighboring regions or countries that share a common water source, ensuring that all stakeholders have equitable access to water resources while minimizing the risk of over-extraction [108, 66, 55, 88, 22, 87, 67, 3, 131, 81].

Additionally, MOO has been applied to optimize the operation of multi-reservoir systems, where different reservoirs serve multiple purposes such as hydropower generation, flood control, and irrigation. These systems require sophisticated optimization techniques to ensure that the various objectives are met without compromising system reliability or environmental sustainability [5, 136, 38, 48, 52, 46, 54, 99, 132, 25].

2 Model Overview

This Paper presents a mathematical model for optimal water resource allocation among four sectors: Agriculture, Industry, Domestic, and Geological. The model aims to maximize economic output, minimize costs, ensure sustainability, and meet specific water demands using data from various government agencies and research papers [49, 17, 56, 29, 62, 93, 70, 111, 112, 15, 109, 40, 44, 64, 19, 42, 63, 12, 43, 130, 124].

3 Objective Functions

Let:

- W_a, W_i, W_d, W_g represent water allocated to agriculture, industry, domestic, and geological sectors, respectively.
- C_a, C_i, C_d, C_g represent water demands for these sectors.
- E_a, E_i, E_d, E_g represent the economic value generated by the sectors.
- S_a, S_i, S_d, S_g represent the sustainability factors for each sector.
- P_a, P_i, P_d, P_g represent the priority factors for each sector, where higher values indicate higher priority.

3.1 1. Maximize Agricultural Output (Economic Benefit)

$$\text{Maximize } Z_1 = E_a(W_a) - \lambda_a (W_a - C_a)^2 \tag{1}$$

Where $E_a(W_a)$ is the economic value generated from agricultural yield based on allocated water W_a. The penalty term $\lambda_a (W_a - C_a)^2$ captures deviations from the optimal crop water requirement.

3.2 2. Minimize Water Allocation Cost for Industry

$$\text{Minimize } Z_2 = C_i \times P_i - E_i(W_i) \tag{2}$$

Where $E_i(W_i)$ is the economic gain from industrial production, and $C_i \times P_i$ captures the cost associated with under- or over-supplying industry needs.

3.3 3. Minimize Domestic Water Shortage

$$\text{Minimize } Z_3 = \sum_{j=1}^{N_d} \left(\frac{W_d(j) - C_d(j)}{C_d(j)} \right)^2 \tag{3}$$

Where $W_d(j)$ and $C_d(j)$ represent the allocated and required water for domestic zone j.

3.4 4. Maximize Geological Sustainability

$$\text{Maximize } Z_4 = S_g(W_g) - \mu_g (W_g - R_g) \tag{4}$$

Where $S_g(W_g)$ represents groundwater sustainability, and $\mu_g (W_g - R_g)$ penalizes water extraction exceeding recharge R_g.

4 Constraints

4.1 1. Water Balance Constraint

$$W_a + W_i + W_d + W_g \leq W_{total} \tag{5}$$

Where W_{total} is the total available water.

4.2 2. Sector-Specific Water Demand Constraints

$$W_a \geq C_a \quad \text{(Agricultural Demand)} \tag{6}$$

$$W_i \geq C_i \quad \text{(Industrial Demand)} \tag{7}$$

$$W_d \geq C_d \quad \text{(Domestic Demand)} \tag{8}$$

$$W_g \geq R_g \quad \text{(Geological Recharge Requirement)} \tag{9}$$

4.3 3. Minimum and Maximum Water Allocation for Sectors

$$W_{a,min} \leq W_a \leq W_{a,max} \tag{10}$$

$$W_{i,min} \leq W_i \leq W_{i,max} \tag{11}$$

$$W_{d,min} \leq W_d \leq W_{d,max} \tag{12}$$

$$W_{g,min} \leq W_g \leq W_{g,max} \tag{13}$$

5 Case Study : Chotanagpur Platue

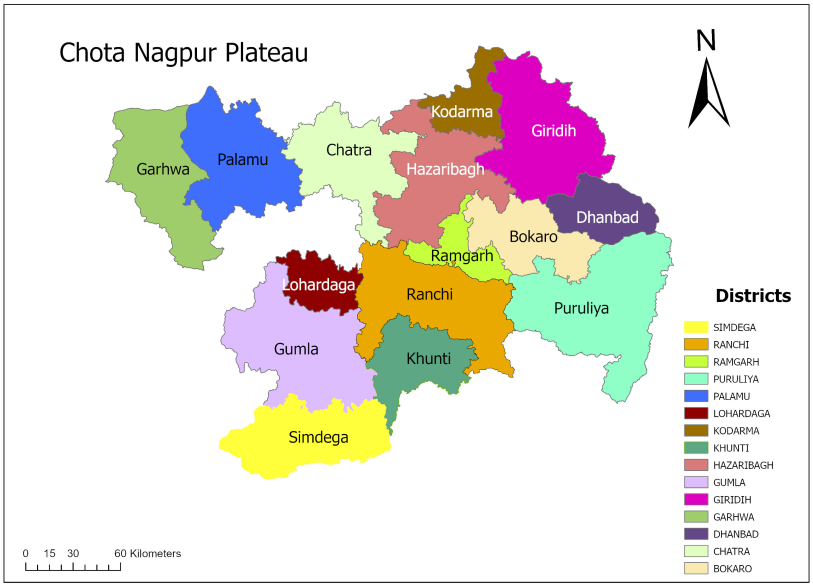
5.1 Chotanagpur Plateau's Geographical Factors

The Chotanagpur Plateau is a well-known geographic area in eastern India that crosses the states of Jharkhand, Bihar, West Bengal, and Chhattisgarh. Recognized for its abundant mineral riches, unique geography, and varied ecosystems, it is essential to the region's socioeconomic and environmental elements. The plateau is made up of several sub-plateaus, including the Ranchi, Hazaribagh, and Koderma plateaus, and has an average elevation of 700 to 1,200 meters. Below, we go into great detail about the Chotanagpur Plateau's geographic features [73, 8, 50, 106, 1, 120, 117, 126, 104, 51].

5.2 Area and Size

The Chotanagpur Plateau is located between the latitudes of 22°N to 24°30' N and the longitudes of 83°E to 86°30' E. It covers an approximate area of 65,000 square kilometers. The work has been carried out of the fourteen districts of Jharkhand namely Simdega, Ranchi, Ramgarh, Palamu, Lohardaga, Koderma, Khunti, Hazaribagh, Gumla, Giridih, Garhwa, Dhanbad, Chatra, Bokaro and Puruliya (Purulia) district of West Bengal.

The plateau has a clear geographical boundary formed by the Mahanadi Basin to the south and the Gangetic Plains to the north. The Maikal Hills border the southwest, and the Rajmahal Hills lie to the northeast [40, 73, 117, 106, 51].



5.3 Structure of Geology

The Chotanagpur Plateau is one of the earliest landmasses in India, having formed during the Precambrian period. The plateau is composed of igneous and metamorphic rocks, including quartzite, gneiss, schist, and granite. It is a component of the Peninsular Shield, which is renowned for its rigidity and stability.

Due to the abundance of resources in the area, such as coal, iron ore, manganese, bauxite, copper, and mica, businesses and mining operations have expanded. Because of the presence of important coalfields like Jharia and Bokaro, this area contributes significantly to India's energy industry [102, 123, 121, 90, 125, 73, 122, 8, 2, 47].

5.4 Landforms and Topography

The Chotanagpur Plateau's geography is made up of a number of erratic hills, valleys, and scattered plateaus. Numerous hill ranges, such as the 600 to 1,000 meter-high Ranchi and Hazaribagh hills, define the topography of the plateau. At 1,365 meters, Parasnath Hill is the tallest hill in the area and a spiritual place for the Jain community [73, 1, 8, 117, 126, 122, 50, 90, 121, 14].

There are three primary sub-regions that make up the plateau:

- **Ranchi Plateau**: This level plateau in the south is renowned for its woodland cover, waterfalls, and visual splendor.
- **Hazaribagh Plateau**: With an average elevation of 600 meters, it is higher and more untamed than the Ranchi Plateau.
- **Koderma Plateau**: Slightly lower in elevation and characterized by narrow ridges, this area is situated further north.

Prominent features such as deep canyons, valleys, and scarps contribute to the harsh and picturesque landscape of the plateau. The plateau's eastern side gently dips towards the Ganga Plain, while its western edge features severe escarpments.

5.5 Temperature

The Chotanagpur Plateau experiences primarily tropical weather with distinct wet and dry seasons. The scorching summer months of March through June have highs of between 30°C and 40°C. The cold weather during the winter months of November through February can reach as low as 5°C in certain places[51].

The southwest monsoon is the main source of the 1,000 to 1,500 mm of yearly rainfall that the area receives on average. Rainfall distribution is unequal, with the western areas receiving less than the eastern ones. The climate of the plateau is suitable for a wide range of plants, from arid scrublands to moist deciduous forests[110].

5.6 System of Drainage

The rivers Damodar, Subarnarekha, Koel, and Barakar dominate the plateau's well-defined drainage system. Because of the uneven topography, these rivers frequently generate rapids and waterfalls as they run through gorges and tight valleys. The steep gradient and heavy sediment load of the Damodar River, also referred to as the "Sorrow of Bengal," make it vulnerable to flooding during the monsoon season [122, 50, 90, 121, 14, 110, 68].

The Chotanagpur Plateau's rivers are primarily seasonal, with the dry months seeing a sharp drop in water levels. Nonetheless, they are essential to agriculture since they provide irrigation for the neighboring areas.

5.7 Types of Soils

The weathering of igneous rocks has created the primarily lateritic and red soils of the Chotanagpur Plateau. These soils are less fruitful because they are low in humus and nitrogen but high in iron and aluminum. Nonetheless, some low-lying regions and valleys have reasonably productive soil that is good for growing paddy and other crops.

Cotton and oilseeds are grown in some locations because of the black soil that exists there, especially in the floodplains and basins [41, 115, 85, 117, 127, 57, 86, 114, 107, 11].

5.8 Economic Activity and Human Settlement

In parts of the Chotanagpur Plateau, there is a high population density made up of both tribal and non-tribal groups. With a practice of shifting agriculture and forestry, tribal communities like the Santhals, Mundas, and Oraons maintain a close relationship with the land and forests.

The main pillars of the economy are mining, industry, and agriculture. Due to the abundant mineral resources on the plateau, numerous large-scale enterprises have been established, including steel factories in Jamshedpur and Bokaro. However, due to overuse of natural resources, the area has problems such as deforestation, soil erosion, and water scarcity [123, 13, 122, 79, 13, 60] .

A location of enormous geographical, ecological, and economic significance, the Chotanagpur Plateau is crucial for both growth and conservation. Due to its distinctive topography, abundant mineral resources, and varied ecosystems, sustainable management is essential to protecting its natural resources and guaranteeing the welfare of its residents.

6 Water Demand Of every district under Chotanagpur Platue

The data provided is as per 8th of october, 2024 retrieved from [62] [93] [64] [63] [19] [42] [43] [124] [124]

District	Month	Agriculture (Water Demand)	Industry (Water Demand)	Domestic (Water Demand)	Ecology (Water Demand)	Agriculture (Economic Value)	Industry (Economic Value)	Ecology (Sustainability factor)
Ranchi	January	70	90	30	20	250	400	100
Ranchi	February	65	85	28	18	230	390	95
Ranchi	March	75	95	32	22	240	410	100
Ranchi	April	85	105	35	25	260	420	105
Ranchi	May	95	115	40	30	275	430	110
Ranchi	June	110	120	45	35	300	450	120
Ranchi	July	120	130	42	38	320	470	125
Ranchi	August	130	125	40	40	330	480	130
Ranchi	September	110	115	38	35	310	460	120
Ranchi	October	100	110	36	30	290	450	115
Ranchi	November	85	100	32	28	270	440	110
Ranchi	December	80	95	30	25	260	430	105
Purulia	January	65	80	29	18	200	500	90
Purulia	February	60	75	27	16	180	490	100
Purulia	March	70	85	31	20	190	510	110
Purulia	April	80	90	34	23	205	520	100
Purulia	May	90	100	39	28	215	530	120
Purulia	June	105	105	44	33	230	540	90
Purulia	July	115	110	41	36	250	560	80
Purulia	August	125	115	39	38	260	570	70
Purulia	September	105	105	36	32	240	550	110
Purulia	October	95	100	34	30	230	540	120
Purulia	November	80	90	30	26	220	530	110
Purulia	December	75	85	28	22	215	520	100
Hazaribagh	January	55	20	25	15	220	380	110
Hazaribagh	February	50	18	23	12	210	370	105
Hazaribagh	March	60	25	27	17	215	400	110
Hazaribagh	April	70	30	30	20	225	410	115
Hazaribagh	May	80	35	35	25	235	420	120

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District	Month	Agriculture (Water Demand)	Industry (Water Demand)	Domestic (Water Demand)	Ecology (Water Demand)	Agriculture (Economic Value)	Industry (Economic Value)	Ecology (Sustainability factor)
Hazaribagh	June	95	32	34	30	250	440	130
Hazaribagh	July	105	30	30	35	265	460	135
Hazaribagh	August	115	28	28	38	270	470	140
Hazaribagh	September	95	25	26	33	255	450	125
Hazaribagh	October	85	22	24	30	245	440	120
Hazaribagh	November	70	20	22	27	235	430	115
Hazaribagh	December	65	18	20	25	230	420	110
Dhanbad	January	80	120	40	30	180	120	120
Dhanbad	February	75	115	38	28	170	110	110
Dhanbad	March	85	130	42	32	175	115	115
Dhanbad	April	95	140	45	35	180	125	125
Dhanbad	May	105	150	50	40	185	130	130
Dhanbad	June	120	145	48	45	195	140	140
Dhanbad	July	130	150	45	50	200	145	145
Dhanbad	August	140	140	43	55	210	150	150
Dhanbad	September	110	130	40	48	190	135	135
Dhanbad	October	100	125	42	45	180	130	130
Dhanbad	November	85	110	40	40	175	125	125
Dhanbad	December	80	105	38	38	170	120	120
Palamu	January	60	30	22	15	45	22	35
Palamu	February	55	28	20	13	42	20	30
Palamu	March	65	35	24	18	50	25	32
Palamu	April	75	40	28	20	55	28	40
Palamu	May	85	45	30	22	60	30	45
Palamu	June	95	42	35	25	70	35	50
Palamu	July	105	40	32	30	80	40	65
Palamu	August	115	38	30	33	75	38	60
Palamu	September	95	35	28	30	65	34	55
Palamu	October	85	32	25	28	55	28	40
Palamu	November	70	30	23	25	50	25	35
Palamu	December	65	28	22	20	45	22	30
Lohardaga	January	50	20	20	10	30	15	20
Lohardaga	February	45	18	18	9	28	14	18
Lohardaga	March	55	22	22	12	35	18	19
Lohardaga	April	65	28	25	15	40	20	22
Lohardaga	May	75	30	30	18	42	21	25
Lohardaga	June	90	28	32	20	50	25	28
Lohardaga	July	100	25	30	22	58	28	35
Lohardaga	August	110	23	28	25	55	27	32
Lohardaga	September	85	20	25	20	50	25	30
Lohardaga	October	75	18	22	18	40	20	25
Lohardaga	November	60	15	20	16	35	18	22
Lohardaga	December	55	12	18	14	30	15	18

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District	Month	Agriculture (Water Demand)	Industry (Water Demand)	Domestic (Water Demand)	Ecology (Water Demand)	Agriculture (Economic Value)	Industry (Economic Value)	Ecology (Sustainability factor)
Gumla	January	40	12	18	8	38	18	18
Gumla	February	35	10	16	6	35	17	16
Gumla	March	45	15	20	10	41	20	17
Gumla	April	55	18	22	12	45	22	20
Gumla	May	65	20	25	15	48	24	23
Gumla	June	80	18	28	18	55	27	26
Gumla	July	90	15	26	20	65	30	30
Gumla	August	100	12	24	22	62	29	29
Gumla	September	75	10	22	20	55	27	27
Gumla	October	65	8	20	18	48	22	22
Gumla	November	50	7	18	15	41	20	19
Gumla	December	45	5	16	12	38	18	16
Simdega	January	30	10	15	7	120	80	150
Simdega	February	28	9	14	6	130	85	150
Simdega	March	35	12	18	8	140	90	145
Simdega	April	40	14	20	10	135	88	138
Simdega	May	50	15	22	12	125	82	135
Simdega	June	60	14	25	15	160	95	160
Simdega	July	70	12	24	17	170	98	180
Simdega	August	80	10	22	20	180	102	175
Simdega	September	60	8	20	18	175	100	168
Simdega	October	55	7	19	15	150	92	170
Simdega	November	45	6	17	13	140	85	165
Simdega	December	40	5	15	10	130	80	155
Khunti	January	50	15	18	9	115	70	100
Khunti	February	45	14	16	8	120	75	102
Khunti	March	55	18	20	10	125	80	98
Khunti	April	65	22	23	12	122	78	95
Khunti	May	75	25	26	15	110	72	93
Khunti	June	85	23	28	18	145	85	115
Khunti	July	95	20	26	20	150	88	128
Khunti	August	100	18	24	22	160	92	124
Khunti	September	80	15	23	19	158	90	117
Khunti	October	70	12	20	17	140	82	120
Khunti	November	60	10	18	15	130	75	116
Khunti	December	55	9	16	12	120	70	109
Ramgarh	January	45	12	20	10	105	95	120
Ramgarh	February	40	11	18	9	110	100	123
Ramgarh	March	50	15	22	12	115	105	119
Ramgarh	April	60	18	25	15	112	103	115
Ramgarh	May	70	20	28	18	100	98	110
Ramgarh	June	80	22	30	20	135	110	127
Ramgarh	July	90	20	27	22	140	115	142

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District	Month	Agriculture (Water Demand)	Industry (Water Demand)	Domestic (Water Demand)	Ecology (Water Demand)	Agriculture (Economic Value)	Industry (Economic Value)	Ecology (Sustainability factor)
Ramgarh	August	100	18	25	25	150	120	138
Ramgarh	September	80	15	23	20	148	118	132
Ramgarh	October	70	12	21	18	130	110	135
Ramgarh	November	60	10	19	16	120	105	130
Ramgarh	December	55	8	17	14	110	100	125
Chatra	January	55	10	17	7	15	10	125
Chatra	February	50	9	15	6	14	9	130
Chatra	March	60	12	20	9	20	12	140
Chatra	April	70	14	23	11	25	15	150
Chatra	May	80	15	25	13	30	20	145
Chatra	June	90	18	30	16	28	18	160
Chatra	July	100	20	28	19	35	25	170
Chatra	August	110	22	30	22	32	23	180
Chatra	September	85	20	26	18	20	14	175
Chatra	October	75	18	24	16	18	13	190
Chatra	November	65	15	22	14	22	16	185
Chatra	December	60	12	20	12	15	11	195
Garhwa	January	40	8	15	5	12	8	100
Garhwa	February	35	7	14	4	11	7	110
Garhwa	March	45	10	18	6	16	10	120
Garhwa	April	55	12	20	8	20	13	135
Garhwa	May	65	15	23	10	25	18	125
Garhwa	June	75	18	26	12	23	15	140
Garhwa	July	85	20	30	15	30	22	150
Garhwa	August	95	22	28	18	28	20	165
Garhwa	September	75	18	24	16	15	10	155
Garhwa	October	65	15	22	14	14	9	170
Garhwa	November	55	12	20	12	18	12	160
Garhwa	December	50	10	18	10	12	8	180
Koderma	January	70	25	28	22	10	5	140
Koderma	February	65	22	26	20	9	6	150
Koderma	March	75	28	30	24	12	8	165
Koderma	April	85	30	32	27	15	10	175
Koderma	May	95	35	35	30	18	12	160
Koderma	June	110	32	33	32	16	11	180
Koderma	July	120	30	30	35	20	15	190
Koderma	August	130	28	28	38	19	14	200
Koderma	September	110	25	26	32	14	9	195
Koderma	October	100	22	25	30	13	8	210
Koderma	November	85	20	23	27	17	10	205
Koderma	December	80	18	21	25	10	6	220
Giridih	January	60	20	22	18	18	12	150
Giridih	February	55	18	20	15	17	11	145

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District	Month	Agriculture (Water Demand)	Industry (Water Demand)	Domestic (Water Demand)	Ecology (Water Demand)	Agriculture (Economic Value)	Industry (Economic Value)	Ecology (Sustainability factor)
Giridih	March	65	22	25	20	22	14	160
Giridih	April	75	25	28	23	25	16	155
Giridih	May	85	30	30	25	30	20	150
Giridih	June	95	32	35	28	28	19	145
Giridih	July	100	30	33	30	35	25	160
Giridih	August	110	28	30	32	33	22	165
Giridih	September	90	25	28	27	21	15	170
Giridih	October	80	22	26	25	19	14	175
Giridih	November	70	20	23	23	24	18	180
Giridih	December	65	18	20	20	18	13	185
Bokaro	January	80	100	35	28	25	40	120
Bokaro	February	75	95	32	25	24	38	115
Bokaro	March	85	105	40	30	30	45	125
Bokaro	April	95	110	45	32	35	50	130
Bokaro	May	105	120	50	38	40	55	125
Bokaro	June	115	130	52	40	38	52	120
Bokaro	July	120	140	55	45	45	60	130
Bokaro	August	130	135	53	50	42	58	135
Bokaro	September	110	125	48	42	30	48	140
Bokaro	October	100	115	45	40	27	46	145
Bokaro	November	85	105	42	38	32	49	150
Bokaro	December	80	100	40	35	25	40	155

7 Results proceeded with Multiobjective Optimization

For generating the task using MOPSO Algorithm [96] was used.

District	Months	Agriculture	Industry	Domestic	Geological
Ranchi	January	70.0	90.0	30.0	20.0
Ranchi	February	65.001	85.00169	28.0	18.00041
Ranchi	March	75.0	95.0	32.0	22.0
Ranchi	April	85.0	105.0	35.0	25.0
Ranchi	May	95.0	115.0	40.0	30.0
Ranchi	June	110.0	120.0	45.0	35.0
Ranchi	July	120.0	130.0	42.0	38.0
Ranchi	August	130.00722	125.0105	40.0	40.00283
Ranchi	September	110.00131	115.00195	38.0	35.000504
Ranchi	October	100.0	110.0	36.0	30.0
Ranchi	November	85.00179	100.00291	32.0	28.000725
Ranchi	December	80.0	95.0	30.0	25.0
Purulia	January	65.0	80.0	29.0	18.0
Purulia	February	60.001016	75.00276	27.0	16.000558

District	Months	Agriculture	Industry	Domestic	Geological
Purulia	March	70.0	85.0	31.0	20.0
Purulia	April	80.0	90.0	34.0	23.0
Purulia	May	90.00013	100.00033	39.0	28.000075
Purulia	June	105.0	105.0	44.0	33.0
Purulia	July	115.0	110.0	41.0	36.0
Purulia	August	125.00014	115.0003	39.0	38.000036
Purulia	September	105.0	105.0	36.0	32.0
Purulia	October	95.0	100.0	34.0	30.0
Purulia	November	80.0	90.0	30.0	26.0
Purulia	December	75.0	85.0	28.0	22.0
Hazaribagh	January	55.0	20.0	25.0	15.0
Hazaribagh	February	50.0	18.0	23.0	12.0
Hazaribagh	March	60.0	25.0	27.0	17.0
Hazaribagh	April	70.00014	30.000256	30.0	20.00007
Hazaribagh	May	80.0	35.0	35.0	25.0
Hazaribagh	June	95.00168	32.00295	34.0	30.000867
Hazaribagh	July	105.0	30.0	30.0	35.0
Hazaribagh	August	115.0	28.0	28.0	38.0
Hazaribagh	September	95.00162	25.002856	26.0	33.00079
Hazaribagh	October	85.00134	22.002384	24.0	30.000647
Hazaribagh	November	70.0	20.0	22.0	27.0
Hazaribagh	December	65.0	18.0	20.0	25.0
Dhanbad	January	80.00043	120.00028	40.0	30.000277
Dhanbad	February	75.0	115.0	38.0	28.0
Dhanbad	March	85.00055	130.00037	42.0	32.00036
Dhanbad	April	95.0	140.0	45.0	35.0
Dhanbad	May	105.0	150.0	50.0	40.0
Dhanbad	June	120.00048	145.00034	48.0	45.00035
Dhanbad	July	130.0	150.0	45.0	50.0
Dhanbad	August	140.0	140.0	43.0	55.0
Dhanbad	September	110.0	130.0	40.0	48.0
Dhanbad	October	100.0007	125.0005	42.0	45.0005
Dhanbad	November	85.0	110.0	40.0	40.0
Dhanbad	December	80.0	105.0	38.0	38.0
Palamu	January	60.0	30.0	22.0	15.0
Palamu	February	55.0	28.0	20.0	13.0
Palamu	March	65.0	35.0	24.0	18.0
Palamu	April	75.0	40.0	28.0	20.0
Palamu	May	85.0	45.0	30.0	22.0
Palamu	June	95.0	42.0	35.0	25.0
Palamu	July	105.0	40.0	32.0	30.0
Palamu	August	115.0	38.0	30.0	33.0
Palamu	September	95.0	35.0	28.0	30.0
Palamu	October	85.0	32.0	25.0	28.0
Palamu	November	70.0	30.0	23.0	25.0
Palamu	December	65.0	28.0	22.0	20.0
Lohardaga	January	50.0	20.0	20.0	10.0
Lohardaga	February	45.0	18.0	18.0	9.0
Lohardaga	March	55.0	22.0	22.0	12.0

District	Months	Agriculture	Industry	Domestic	Geological
Lohardaga	April	65.0	28.0	25.0	15.0
Lohardaga	May	75.0	30.0	30.0	18.0
Lohardaga	June	90.0	28.0	32.0	20.0
Lohardaga	July	100.0	25.0	30.0	22.0
Lohardaga	August	110.0	23.0	28.0	25.0
Lohardaga	September	85.0	20.0	25.0	20.0
Lohardaga	October	75.0	18.0	22.0	18.0
Lohardaga	November	60.0	15.0	20.0	16.0
Lohardaga	December	55.0	12.0	18.0	14.0
Gumla	January	40.0	12.0	18.0	8.0
Gumla	February	35.0	10.0	16.0	6.0
Gumla	March	45.0	15.0	20.0	10.0
Gumla	April	55.0	18.0	22.0	12.0
Gumla	May	65.0	20.0	25.0	15.0
Gumla	June	80.0	18.0	28.0	18.0
Gumla	July	90.0	15.0	26.0	20.0
Gumla	August	100.0	12.0	24.0	22.0
Gumla	September	75.0	10.0	22.0	20.0
Gumla	October	65.0	8.0	20.0	18.0
Gumla	November	50.0	7.0	18.0	15.0
Gumla	December	45.0	5.0	16.0	12.0
Simdega	January	30.0	10.0	15.0	7.0
Simdega	February	28.0	9.0	14.0	6.0
Simdega	March	35.0	12.0	18.0	8.0
Simdega	April	40.0	14.0	20.0	10.0
Simdega	May	50.0	15.0	22.0	12.0
Simdega	June	60.0	14.0	25.0	15.0
Simdega	July	70.0	12.0	24.0	17.0
Simdega	August	80.0	10.0	22.0	20.0
Simdega	September	60.00076	8.000432	20.0	18.00072
Simdega	October	55.0	7.0	19.0	15.0
Simdega	November	45.0	6.0	17.0	13.0
Simdega	December	40.0	5.0	15.0	10.0
Khunti	January	50.0	15.0	18.0	9.0
Khunti	February	45.0	14.0	16.0	8.0
Khunti	March	55.0	18.0	20.0	10.0
Khunti	April	65.0	22.0	23.0	12.0
Khunti	May	75.0	25.0	26.0	15.0
Khunti	June	85.0	23.0	28.0	18.0
Khunti	July	95.0	20.0	26.0	20.0
Khunti	August	100.0	18.0	24.0	22.0
Khunti	September	80.0	15.0	23.0	19.0
Khunti	October	70.0	12.0	20.0	17.0
Khunti	November	60.0	10.0	18.0	15.0
Khunti	December	55.0	9.0	16.0	12.0
Ramgarh	January	45.0	12.0	20.0	10.0
Ramgarh	February	40.0	11.0	18.0	9.0
Ramgarh	March	50.0	15.0	22.0	12.0
Ramgarh	April	60.0	18.0	25.0	15.0

District	Months	Agriculture	Industry	Domestic	Geological
Ramgarh	May	70.0	20.0	28.0	18.0
Ramgarh	June	80.0	22.0	30.0	20.0
Ramgarh	July	90.0019	20.00155	27.0	22.00191
Ramgarh	August	100.0	18.0	25.0	25.0
Ramgarh	September	80.0	15.0	23.0	20.0
Ramgarh	October	70.0	12.0	21.0	18.0
Ramgarh	November	60.0	10.0	19.0	16.0
Ramgarh	December	55.0	8.0	17.0	14.0
Chatra	January	55.0	10.0	17.0	7.0
Chatra	February	50.0	9.0	15.0	6.0
Chatra	March	60.0	12.0	20.0	9.0
Chatra	April	70.0	14.0	23.0	11.0
Chatra	May	80.0	15.0	25.0	13.0
Chatra	June	90.0	18.0	30.0	16.0
Chatra	July	100.0	20.0	28.0	19.0
Chatra	August	110.0	22.0	30.0	22.0
Chatra	September	85.0	20.0	26.0	18.0
Chatra	October	75.0	18.0	24.0	16.0
Chatra	November	65.0	15.0	22.0	14.0
Chatra	December	60.0	12.0	20.0	12.0
Garhwa	January	40.0	8.0	15.0	5.0
Garhwa	February	35.0	7.0	14.0	4.0
Garhwa	March	45.0	10.0	18.0	6.0
Garhwa	April	55.0	12.0	20.0	8.0
Garhwa	May	65.0	15.0	23.0	10.0
Garhwa	June	75.0	18.0	26.0	12.0
Garhwa	July	85.0	20.0	30.0	15.0
Garhwa	August	95.0	22.0	28.0	18.0
Garhwa	September	75.0	18.0	24.0	16.0
Garhwa	October	65.0	15.0	22.0	14.0
Garhwa	November	55.0	12.0	20.0	12.0
Garhwa	December	50.0	10.0	18.0	10.0
Koderma	January	70.0	25.0	28.0	22.0
Koderma	February	65.0	22.0	26.0	20.0
Koderma	March	75.0	28.0	30.0	24.0
Koderma	April	85.0	30.0	32.0	27.0
Koderma	May	95.0	35.0	35.0	30.0
Koderma	June	110.0	32.0	33.0	32.0
Koderma	July	120.0	30.0	30.0	35.0
Koderma	August	130.0	28.0	28.0	38.0
Koderma	September	110.0	25.0	26.0	32.0
Koderma	October	100.0	22.0	25.0	30.0
Koderma	November	85.0	20.0	23.0	27.0
Koderma	December	80.0	18.0	21.0	25.0
Giridih	January	60.0	20.0	22.0	18.0
Giridih	February	55.0	18.0	20.0	15.0
Giridih	March	65.0	22.0	25.0	20.0
Giridih	April	75.0	25.0	28.0	23.0
Giridih	May	85.0	30.0	30.0	25.0

District	Months	Agriculture	Industry	Domestic	Geological
Giridih	June	95.0	32.0	35.0	28.0
Giridih	July	100.0	30.0	33.0	30.0
Giridih	August	110.0	28.0	30.0	32.0
Giridih	September	90.0	25.0	28.0	27.0
Giridih	October	80.0	22.0	26.0	25.0
Giridih	November	70.0	20.0	23.0	23.0
Giridih	December	65.0	18.0	20.0	20.0
Bokaro	January	80.0	100.0	35.0	28.0
Bokaro	February	75.0	95.0	32.0	25.0
Bokaro	March	85.0	105.0	40.0	30.0
Bokaro	April	95.0	110.0	45.0	32.0
Bokaro	May	105.0	120.0	50.0	38.0
Bokaro	June	115.0	130.0	52.0	40.0
Bokaro	July	120.0	140.0	55.0	45.0
Bokaro	August	130.0	135.0	53.0	50.0
Bokaro	September	110.0	125.0	48.0	42.0
Bokaro	October	100.0	115.0	45.0	40.0
Bokaro	November	85.0	105.0	42.0	38.0
Bokaro	December	80.0	100.0	40.0	35.0

8 Conclusion

The study emphasizes how important multiobjective optimization (MOO) is for handling conflicting and intricate demands on water supplies. The necessity of using cutting-edge optimization techniques is highlighted by the increasing strain that economic activity, population increase, and climate change are placing on water resources. It is common for traditional single-objective methods to water resource management to fall short in addressing the multifaceted character of the issue, which involves striking a balance between the needs for water from the environment, industry, agriculture, and homes.

As previously said, the increased variability of water availability due to climate change affects water management even more. Therefore, it is critical to implement techniques that are not only optimal but also robust and adaptable to uncertainty. Water resource managers can create resilient policies that guarantee long-term sustainability even in the face of harsh weather by adding future forecasts of climate variability into MOO models. This flexibility is essential for areas vulnerable to floods and droughts, where the availability and shortage of water might change suddenly.

Furthermore, the optimization of multi-reservoir systems—which are useful for irrigation, flood control, and hydropower—highlights the effectiveness of MOO in controlling intricate and expansive water systems. For these systems to remain reliable and environmentally sustainable, conflicting goals must frequently be carefully balanced. Water managers can create plans that satisfy different stakeholders' demands and maintain ecological balance by applying advanced optimization techniques.

This paper highlights the practical use of MOO in water resource allocation through case studies and examples. From transboundary water sharing to river basin management, MOO has been crucial in settling disputes and guaranteeing the fair allocation of water resources between industries. It is clear that incorporating MOO into water management techniques provides a viable approach to resolving the complex issues related to the distribution of water resources.

Multiobjective optimization will be essential in developing policies and plans that strike a balance between social justice, environmental preservation, and economic growth as water scarcity and demand continue to rise. In addition to being a technological fix, using MOO in water management is an essential step in the direction of attaining sustainable development objectives. Decision-makers can guarantee that water resources are managed in a way that satisfies the demands of both the current and future generations while preserving essential ecosystems by adopting MOO. Therefore, more study and advancement in this area are essential to enhancing MOO frameworks' capabilities and expanding their suitability for a variety of water management scenarios.

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