

**A FRAMEWORK MODEL FOR SUSTAINABLE WATER-SHARING  
AMONG CO-BASIN STATES OF A RIVER BASIN**

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**A FRAMEWORK MODEL FOR SUSTAINABLE WATER-SHARING  
AMONG CO-BASIN STATES OF A RIVER BASIN**

**by**

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**Submitted**

**in fulfilment of the requirements of the degree of Doctor of Philosophy  
to the**



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## **CERTIFICATE**

This is to certify that the thesis entitled, “**A FRAMEWORK MODEL FOR SUSTAINABLE WATER-SHARING AMONG CO-BASIN STATES OF A RIVER BASIN**” being submitted by Mr. Shambhu Azad to the Indian Institute of Technology, Delhi, India, for the award of the degree of DOCTOR OF PHILOSOPHY, is a record of bona fide research work carried out by him under my supervision and guidance. This thesis work, in my opinion, has reached the standard, fulfilling the requirement of DOCTOR OF PHILOSOPHY degree. The research report and the result presented in this thesis have not been submitted, in part or in full, to any other university or institute, for the award of any degree or diploma.

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## सार

वर्तमान अध्ययन में, एक नए ढांचे के मॉडल को जल आवंटन के लिए गवर्निंग चर के आधार पर अवधारणा और सूत्रबद्ध किया गया है, ताकी सह-बेसिन राज्यों के बीच पानी के उचित और न्यायसंगत आवंटन के लिए निष्पक्षता बढ़ाने के प्रयास में मदद मिले। एक ही पैमाने पर एक नदी बेसिन के विभिन्न सह-बेसिन राज्यों के गवर्निंग चर को लाने के लिए गवर्निंग चर को सामान्यीकृत किया गया है। जल आवंटन के लिए सह-बेसिन राज्यों को सौंपे जाने वाले वजन का मूल्यांकन करने के उद्देश्यपूर्ण तरीकों की अनुपस्थिति में, विभिन्न सह-बेसिन राज्यों के लिए, एक रूपरेखा परिकल्पित और भारोत्तोलन के निर्धारण के लिए भी सूत्रबद्ध की गई है, जो कि गवर्निंग चर के एक कृत्य के रूप में की गई है। किसी भी सह-बेसिन राज्य को पानी का आवंटन इक्विटी के लिए अपने संघर्ष के लिए आनुपातिक माना गया है, जो की प्रत्येक सह-बेसिन राज्य के सामान्य असंतोष, संतुष्टि, और वजन कारकों का एक कृत्य माना गया है। सिस्टम डायनेमिक्स का उपयोग प्रस्तावित मॉडल निर्माण का दरसाने के लिए और हल करने के लिए प्रभावी ढंग से किया गया है। प्रस्तावित मॉडल को वास्तविक नदी घाटियों के लिए प्रयोज्यता और मजबूती का परीक्षण करने के लिए दो नदी घाटियों, अर्थात्, भारत की वम्सधारा और कावेरी नदी बेसिन पर लागू किया गया है। प्रस्तावित मॉडल को सफलतापूर्वक वम्सधारा नदी बेसिन में लागू किया गया है, और प्रस्तावित मॉडल मापदंडों के व्यापक स्पेक्ट्रम संभावित मान पर प्रस्तावित मॉडल अभिसरण और वैधता के संदर्भ में इसकी मजबूती साबित करने के लिए प्रस्तावित मॉडल मापदंडों का संवेदनशीलता विश्लेषण किया गया है। यह समाधान ओडिशा सह-बेसिन राज्य के मामले में 1444 मिलियन क्यूबिक मीटर (एमसीएम) और आंध्र प्रदेश के सह-बेसिन राज्य के लिए 1067 एमसीएम के अंतिम आवंटन में जल्दी से परिवर्तित हो गया। संवेदनशीलता विश्लेषण से पता चला है कि प्रस्तावित मॉडल का आवंटन गवर्निंग चर को दिए गए महत्वपूर्ण भार के आधार पर ओडिशा राज्य के लिए 1584 एमसीएम से 1336 एमसीएम और आंध्र के लिए 927 से 1175 एमसीएम तक प्राप्त कर सकते हैं।

कावेरी नदी बेसिन के लिए अध्ययन में, कावेरी नदी बेसिन के सह-बेसिन राज्यों के बीच पानी के बंटवारे के लिए कावेरी जल विवाद न्यायाधिकरण पुरस्कार का विश्लेषण किया गया है और उसी डेटा का विश्लेषण करके प्रस्तावित मॉडल का उपयोग करके प्राप्त परिणामों की तुलना में इसका उपयोग किया गया है। अधिनिर्णय अध्ययन ने प्रदर्शित किया कि ट्रिब्यूनल का फैसला कावेरी बेसिन में सामान्य पानी की उपलब्धता वर्ष के लिए, पानी के बंटवारे की समस्या को

हल करने में असमर्थ है। ऐसा इसलिए है क्योंकि कावेरी बेसिन में सामान्य पानी की उपलब्धता आंकड़ों के विश्लेषण से पता चला है कि सह-बेसिन राज्यों की विभिन्न हाइड्रोलॉजिकल स्थितियों ने भी कावेरी बेसिन में सामान्य रूप से कुल पानी की उपलब्धता उत्पन्न की, लेकिन ट्रिब्यूनल ने इस तथ्य पर विचार नहीं किया। वही समस्या कावेरी बेसिन की पानी की उपलब्धता के लिए निर्भरता के विभिन्न स्तरों के लिए ट्रिब्यूनल द्वारा सह-बेसिन राज्यों के बीच जल वितरण में बनी रही। यद्यपि ट्रिब्यूनल ने सह-बेसिन राज्यों के बीच पानी के उचित और न्यायसंगत तुष्टिकरण के लिए बर्लिन सिद्धांत पर विचार किया था, लेकिन इसने मुख्य रूप से सिंचित क्षेत्रों और पानी की दक्षता क्षमता का मिलान, कावेरी बेसिन की पानी की उपलब्धता के साथ करके तर्कसंगत निर्णयों के संयोजन के आधार पर पानी का वितरण किया। हालांकि, मॉडल के परिणामों ने विभिन्न सह-बेसिन राज्यों को अलग-अलग आवंटन का प्रदर्शन किया, जो कि व्यक्तिगत सह-बेसिन राज्यों की हाइड्रोलॉजिकल स्थितियों पर निर्भर करता है, यहां तक कि ट्रिब्यूनल द्वारा अनुशंसित पानी के स्थैतिक आवंटन के खिलाफ कावेरी बेसिन की एक सामान्य पानी की उपलब्धता के लिए भी। मॉडल ने सिफारिश की है, कि कावेरी बेसिन की एक सामान्य पानी की उपलब्धता के दौरान सह-बेसिन राज्यों की हाइड्रोलॉजिकल परिस्थिति के आधार पर तमिलनाडु तमिलनाडु के लिए पानी का आवंटन 380 हजार मिलियन क्यूबिक फीट (टीएमसी) से 399.4 टीएमसी तक, कर्नाटक के लिए 278.1 टीएमसी से 315.2 टीएमसी, केरल के लिए 42.5 टीएमसी से 45.2 टीएमसी और पॉन्डिचेरी के लिए 5.6 टीएमसी से 6.2 टीएमसी तक भिन्न होगा यद्यपि, ट्रिब्यूनल द्वारा प्रस्तावित जल आवंटन के स्थिर मूल्यों के आधार पर, कावेरी बेसिन की सामान्य पानी की उपलब्धता के लिए, तमिलनाडु के लिए 419 टीएमसी के, कर्नाटक के लिए 270 टीएमसी, केरल के लिए 30 टीएमसी, और पॉन्डिचेरी के लिए 7 टीएमसी वितरण किया। अध्ययन ने प्रदर्शित किया कि प्रस्तावित मॉडल को लागू करके सह-बेसिन राज्यों के बीच जल आवंटन में अधिक निष्पक्षता हासिल की जा सकती है, क्योंकि मॉडल पानी के उचित और समान वितरण के लिए उद्देश्यपूर्ण तरीके से विभिन्न गवर्निंग चर के प्रभावों पर विचार कर सकता है। उसी रूप में जिसकी चर्चा की गई है, उस हैसियत से, प्रस्तावित मॉडल में सह-बेसिन राज्यों के बीच पानी के उचित और न्यायसंगत वितरण के लिए एक उद्देश्यपूर्ण तरीके से ट्रांस-बाउन्ड्री जल आवंटन समस्याओं को हल करने की क्षमता है।

## ABSTRACT

In the present study, a new framework model was conceptualised and formulated based on governing variables for water allocation; in an effort to enhance the objectivity for a reasonable and equitable allocation of water among co-basin states. The governing variables were normalised to reduce the governing variable of different co-basin states of a river basin on the same scale. In the absence of objective methods for evaluating the weights to be assigned to co-basin states for water allocation, a framework was also conceptualised and formulated for determination of the weightage of different co-basin states as a function of the governing variables. The water allocation to any co-basin state had been assumed to be proportional to its struggle for equity, which in turn was assumed to be a function of the normalised discontent, satisfaction, and weighting factors of each co-basin state. System dynamics was used effectively to represent and solve the proposed model formulation. The proposed model was applied to two river basins, namely, the Vamsadhara and the Cauvery river basin of India, to test applicability and robustness for real river basins. The proposed model was successfully applied to the Vamsadhara river basin, and sensitivity analysis of the proposed model parameters was carried out to prove its robustness in terms of the proposed model convergence and validity over the broad-spectrum values of the proposed model parameters. The solution converged quickly to a final allocation of 1444 million cubic metre (MCM) in the case of the Odisha co-basin state, and 1067 MCM for the Andhra Pradesh co-basin state. The sensitivity analysis showed that the proposed model's allocation varied from 1584 MCM to 1336 MCM for Odisha state and from 927 to 1175 MCM for Andhra, depending upon the importance weights given to the governing variables.

In application to the Cauvery river basin, the Cauvery Water Disputes Tribunal award for water sharing among the co-basin states of the Cauvery river basin was analyzed and compared with the results obtained by using the proposed model by analyzing the same data that was used by the tribunal. The study demonstrated that the tribunal award was unable to



resolve the water-sharing problem even for a year with a normal yield in the Cauvery basin. This is because the analysis of the Cauvery basin yield data revealed that the different hydrological conditions of the co-basin states also generated normal yield in the Cauvery basin as a whole, but the tribunal did not consider this fact. The same problem persisted in the water distribution among co-basin states by the tribunal for different levels of dependability for the yields of the Cauvery basin. Although the tribunal considered the Berlin principle for a reasonable and equitable apportionment of water among co-basin states, but it primarily distributed the water based on a combination of rational as well as subjective decisions by adjusting the irrigated areas and water application efficiencies to match the demands with the available yield of the Cauvery basin. However, the results of the model demonstrated different allocations to different co-basin states depending upon the hydrological conditions of the individual co-basin states, even for a normal yield of the Cauvery basin against the static allocation of water recommended by the tribunal. The model recommended that the water allocation be varied from 380 thousand million cubic feet (TMC) to 399.4 TMC for Tamil Nadu, from 278.1 TMC to 315.2 TMC for Karnataka, from 42.5 TMC to 45.2 TMC for Kerala, and from 5.6 TMC to 6.2 TMC for Pondicherry depending upon the hydrological conditions of the co-basin states during a normal yield of the Cauvery basin, against the static values of water allocation proposed by the tribunal of 419 TMC for Tamil Nadu, 270 TMC for Karnataka, 30 TMC for Kerala, and 7 TMC for Pondicherry for the normal yield of the Cauvery basin. The study demonstrated that more objectivity could be achieved in the water allocation among co-basin states by applying the proposed model, as the model can consider the effects of different governing variables in an objective manner for a reasonable and equitable distribution of water. As such, the proposed model has the potential to resolve the transboundary water allocation problems in an objective manner for a reasonable and equitable distribution of water among co-basin states.

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## ACRONYMS AND ABBREVIATIONS

ARC	Administrative reform commission
CA	Catchment Area
CCA	Culturable Command Area
CFFC	Cauvery Fact Finding Committee
CRA	Cauvery Regulatory Authority
CMC	Cauvery Monitoring Committee
CMB	Cauvery Management Board
CWC	Central Water Commission
CWDT	Cauvery Water Dispute Tribunal
ha	Hectare
IMD	India Meteorological Department
ISWD	Inter State Water Dispute
KWDT	Krishna Water Dispute Tribunal
LCA	Lower Coleroon Anicut
MCM	Million Cubic Metre
MDB	Murray Darling Basin
MW	Megawatt
NCA	Narmada Control Authority
NE	North East
SLP	Special Leave Petition
SW	South West
SC	Supreme Court
TMC	Thousand Million Cubic feet
UN	United Nations

UNDP	United Nations Development Programme
VRB	Vamsadhara River Basin
WA	Water Availability
DMNL	Dimensionless
SDCA	Southern African Development Community
Sq. Km.	Kilometre square
Govt.	Government
MSL	Mean Sea Level

## NOTATIONS AND SYMBOLS

AA(i)	Arable areas of the $i^{\text{th}}$ state	Sq. Km
ALC(i)	Allocation of water to the $i^{\text{th}}$ co-basin state	MCM
$\Delta$ ALC(i)	Change in the allocation for the $i^{\text{th}}$ co-basin state	MCM
DCT(i)	Normalised discontent of the $i^{\text{th}}$ co-basin state	DMNL
DIW	Demand influence weights	DMNL
DIW (j)	Demand side Influence weight of the $j^{\text{th}}$ variable	DMNL
DSF	Demand-side factors	DMNL
DSF ( i, j)	$j^{\text{th}}$ demand-side factors for the $i^{\text{th}}$ co-basin state	DMNL
DSV ( i, j)	$j^{\text{th}}$ demand variable for the $i^{\text{th}}$ co-basin state	MCM
DSV ( i, r)	$r^{\text{th}}$ demand variable for the $i^{\text{th}}$ co-basin state	MCM
IW(K)	Importance weights for all supply-side variables	DMNL
i	Index of the co-basin state	DMNL
j	Index of the demand side variable	DMNL
k	Index of the supply side variable	DMNL
Kc	Time constant	Per Sec.
n	Number of the co-basin states	DMNL
p	Number of demand-side variables	DMNL
PWD(j)	Priority weight for the $j^{\text{th}}$ demand-side variable	DMNL
PWS(k)	Priority weight for the $k^{\text{th}}$ supply-side variables	DMNL

PWD (r)	Priority weight for the $r^{\text{th}}$ demand-side variable	DMNL
PWS (s)	Priority weight for the $s^{\text{th}}$ supply-side variables	DMNL
q	Number of supply side variables	DMNL
SFE	Struggle for equity	DMNL
SFE (i)	Struggle for equity for the $i^{\text{th}}$ state	DMNL
SIW (k)	Supply-side influence weight of $k^{\text{th}}$ supply side variable	DMNL
SSF	Supply-side factors	DMNL
SSF ( i, k)	Supply side factor for the $k^{\text{th}}$ supply variable $i^{\text{th}}$ co-basin state	DMNL
SSV (i, k)	$k^{\text{th}}$ supply-side variable for the $i^{\text{th}}$ co-basin state	MCM
SFE(i)	Struggle for equity for the $i^{\text{th}}$ co-basin state	DMNL
STF(i)	Normalised satisfaction level of the $i^{\text{th}}$ co-basin state.	DMNL
TGT(i)	Targeted amount of water of the $i^{\text{th}}$ co-basin states	MCM
w(i)	weighting factor for $i^{\text{th}}$ state	DMNL
$\alpha$	Overall weight of the demand variables	DMNL
$\beta$	Overall weight of the supply variables	DMNL