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Bindhy Wasini Pandey
Subhash Anand *Editors*

Water Science and Sustainability

Springer

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In the Honour of Prof. R. B. Singh
Secretary General IGU, Member ICSU

About This Book

Water is the most vital resource for the existence of life on earth. It is a prime natural measure, a basic human need and a precious national asset. Water is indispensable for the existence of natural habitat, biosphere and forms an essential element in the socio-economic development of the ecosphere. Water forms the living mass, together with the soil and air, represents the living environment. Water is an important constituent of the geosystem. It is the most abundant substance on the earth which links the three components of the geosystem by means of an endless circulatory movement called the hydrological cycle. Water is a key factor in the air—conditioning the earth for human existence and delineating the geomorpho1ogy. Water is not only vital for the sustenance of life, but also essential for socio-economic development. The ecological balance maintained by the quality of water available to a large extent determines the way of life of the people.

The book *Sustainable Development Goal Series: Water Science and Sustainability* describes the importance of water resources for socio-economic and ecological development including geomorphic and ecological environments. Hence, conservation, management and development of water resources have become very necessary for the development of man and the environment.

This book is an outcome of the valuable contributions made by eminent scientists and research scholars who have been trying to develop alternative strategies, solutions and models for sustainable water resources development through research, monitoring and experiments varying from regional to global scale. This edition would be of immense use to the policymakers, environmentalists, ecologists, academicians, research scholars and people in general concerned with water resources management.

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About the Editors

Bindhy Wasini Pandey is currently an Associate Professor of Geography at the Department of Geography, Delhi School of Economics, University of Delhi. He has to his credit 24 Years of Teaching and Research experience, 08 books and 70 research papers published in books and journals. He has supervised 0 Ph.D. and 05 M.Phil. Theses. He has received Young Geographers Awards of National Association of Geographers India (NAGI) and Shastri Indo-Canadian Institute (SICI) and Canadian International Development Agency (CIDA) Fellowship for the project on Hazard Zone Mapping in Himachal Himalaya and British Columbia, Canada in 1995. He has widely travelled and attended International Conferences and delivered lectures in about 35 countries. Dr. Pandey is specialized in Marginality Analysis and Vulnerability Assessment in High Altitudes. He is the Deputy Executive of International Geoscience Education Organization (IGEO), and Sectional Recorder, Earth System Sciences of Indian Science Congress (ISCA). He is also Secretary of IGU Commission on Biogeography and Biodiversity.

Subhash Anand is currently an Associate Professor of Geography at the Department of Geography, Delhi School of Economics, University of Delhi. He has to his credit 23 Years of Teaching and Research experience, 06 books and 40 research papers published in books and journals. Dr. Anand is a specialist in Urban Solid Waste Management and Planning, Sustainability, and Geoparks. He has widely travelled and attended International Conferences and delivered lectures in about 30

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Professor R. B. Singh

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Shouraseni Sen Roy

Abstract

Professor Singh is the first Indian Geographer to have the dual distinction of holding the position of the IGU Secretary General and ICSU Scientific Committee Member. He was the first Indian and second Asian Secretary General and Treasurer of the IGU. He has been elected as the Vice President of IGU for two terms since 2012. Professor R. B. Singh is a Distinguished Geographer in Environmental Geography and GIS applications, who has made distinct academic contributions over the last five decades. His reputation spreads beyond academic and national boundaries. He is an excellent mentor, guide, and life-long advisor to his students. His success as a mentor to his students is evident from the fact that he has supervised 40 Ph.D., 82 M. Phil, Research Scholars and countless MA students. He was Chair, UGC National Committee-Learning Outcome Based Curriculum Framework since July 2018. Expert in the prestigious Committees of the Government of India-Ministry of Environment and Forests, Department of Science and Technology, National Disaster Management Authority (NDMA). Taught courses to M.A., M.Phil., and Ph.D. programs at University of Delhi. Undertaken Major International Collaborative Research Projects, he has written and edited more than 50 books and more than 230 Research Papers.

Keywords

Professor R. B. singh · IGU · ICSU · Secretary general · Vice president

Professor R. B. Singh is a distinguished Geographer in Environmental Geography and GIS applications, who has made distinct academic contributions over the last five decades. His reputation spreads beyond academic and national boundaries. All of his achievements are through sheer dedication and hard work in the field of Geography. Therefore, it comes as no surprise to anyone that Prof. Singh currently is the most well-known Indian Geographer and expert of environmental issues both inside and outside India. Throughout his career, he has achieved many "Firsts" as an Indian Geographer, thus making him a role model for the entire Geography community. Given his long list of achievements over almost five decades, it is not easy to describe his achievements in a few pages. In the sections below, I have summarized some of his major contributions throughout his long career.

Professor Singh has a great contribution in research particularly outside India, he is

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considered to be an excellent research collaborator, who makes the impossible possible. Throughout my interactions with Prof. Singh, I have always been amazed at the variety of research collaborators that are in his office all the time. His research collaborations span across all six continents. He has written 14 books, 35 edited research volumes, and more than 200 research papers published in national and international journals. He was recently invited by the UN to moderate a Working Group on Exposure and Vulnerability at UNISDR Science and Technology Conference on Sendai Framework of Disaster Risk Reduction, 2015–2030, Geneva. He also served as a panelist on *Science Advise in Times of Disaster Emergencies* in South Africa. Thus he has been very generous with his time and sharing his knowledge with the wider academic and policymakers' communities. He has published in well-known high impact international peer-reviewed journals, including published in Journals-Climate Dynamics, Current Science, Singapore Jl. Of Tropical Geography, Energies, Theoretical and Applied Climatology, Environmental Science and Policy, Physical Geography, Advances in Meteorology, Physics and Chemistry of the Earth, Agriculture, Ecosystem and Environment, Hydrological Processes, Mountain Research and Development, Journal of Mountain Science. He is Springer Series Editor—Advances in Geographical and Environmental Sciences; and Sustainable Development Goals (SDGs), IAP–Global Network of Science Academies representative on Disaster Risk Reduction.

Professor Singh as a Project Director/Principal Investigator has Undertaken Collaborative Major Research Projects on Livelihood Security in Changing Socio-Economic Environment in Himachal Pradesh, India (2012 onwards) collaborated with University of Turku, Finland, Shastri Applied Research Project (SHARP) on Role of Public, Private and Civil Sectors in Sustainable Environmental Management (2003–2005) collaborated with University Of Manitoba and the University of Winnipeg, Winnipeg, Canada, ICSSR—Indo-Dutch Programme on Alternative in Dev. (IDPAD) on Environmental Implications and its Socio-Economic Implications in Rural-Urban Fringe of Delhi—University of Delhi & University of Groningen, The Netherlands. (1997–2002), CIDA-SICI Partnership Project-II on Urban Development and Environmental Impacts in Mountain Context, University of Delhi & University of Manitoba, Canada. (1998–2002), DFID Res. Project on Enhancing Food Chain Integrity…Pollution Impact on Vegetable System (2000–2002) in Peri-Urban Areas, Collaboration with Imperial College, London, UK., CIDA-SICI Partnership Project-I on Sustainable Development of Mountain Environment in India and Canada, University of Delhi & University of Manitoba, Canada, (1994–1997), Ministry of Agriculture Project for Preparation of Perspective Plan for Land Resources in N. Zone, India (1994).

Professor Singh, is the first Indian Geographer to have the dual distinction of holding the position of the IGU Secretary General and ICSU Scientific Committee Member. He was the first Indian and second Asian Secretary General and Treasurer of the IGU. He has been elected as the Vice President of IGU for two terms since 2012. He was awarded the prestigious Japan Society for Promotion of Science (JSPS) Research Fellowship at Hiroshima in 2013, and many travel fellowships/support from UNEP, UNITAR, UNISDR, IAP, UNU, UNCRD, WCRP, IAHS, IGU, NASDA, INSA, UGC, SICI, MAIRS, and University of Delhi etc. for participating and presenting papers at different international conferences. He was also the Chair of the Department of Geography, University of Delhi during 2013–2016, when the department was ranked as one of the best Geography Departments in India. He was invited by UGC for Preparing National Level CBCS Syllabus for Undergraduate Geography in 2015. He is also Chair of the UGC prestigious committee for preparing Learning Outcome based Curriculum Framework since July 2018. He has served as an expert on different prestigious Committees of the Government of India - Ministry of Environment and Forests, Department of Science and Technology, National Disaster Management Authority (NDMA), ICSSR, CSIR, etc. He has presented his research

and participated in numerous research projects across more than 40 countries including the like USA, Canada, Mexico, Japan, Australia, France, Finland, Denmark, Spain, UK, Netherlands, Norway, Germany, Switzerland, Russia, Georgia, Armenia, Poland, Czech Rep., Mongolia, Malaysia, Thailand, Egypt, China, Taiwan, Tunisia, Sweden, Israel, South Korea, Ireland, South Africa, Brazil, Singapore, Italy, Luxembourg, Sri Lanka, Indonesia, Nepal and Bhutan. Recently, he was unanimously elected president of the Earth System Science Section of the Indian Science Congress Association (ISCA). In 1988, the UNESCO/ISSC (Paris) awarded Research and Study Grants Award in Social and Human Sciences. He has to his credit of several Travel Fellowships/Support from UNEP, UNITAR, UNU, UNCRD, WCRP, IAHS, IGU, NASDA, INSA, UGC, SICI, MAIRS, and University of Delhi etc. for participating and presenting papers, Chairing session and discussing research projects in USA, Canada, Mexico, Japan, Australia, France, Finland, Denmark, Spain, UK, Netherlands, Norway, Germany, Switzerland, Russia, Georgia, Armenia, Poland, Czech Rep., Mongolia, Malaysia, Thailand, Egypt, China, Taiwan, Tunisia, Sweden, Israel, South Korea, Ireland, South Africa, Brazil, Singapore, Sri Lanka, Indonesia, Italy, Luxembourg, Kyrgyz Republic, Nepal, and Bhutan.

Professor Singh is an excellent mentor, guide, and life-long advisor to his students. His success as a mentor to his students is evident from the fact that he has supervised 33 Ph.D., 80 M.Phil., and countless M.A. students. He always encourages his students to explore new research areas, and present at various national and international conferences. He actively publishes with his students, and many of them have followed him in his footsteps for an academic career. His effectiveness as a mentor is evident from the fact that his former students have stayed in touch with him many years after graduation. They often come back to him for advice and guidance, for which he is always available. He is never hesitant to showcase his students by recommending them to various opportunities. He has taught a wide variety of courses in Environment and Ecology, Remote Sensing, Urbanization Impacts, Natural Resources, and Biogeography. This is indicative of his wide scope of specialization and expertise. As one of his students, I myself will always be grateful to him for getting me interested in higher education and research, and choosing academics as my career.

Thus, many who know Prof. Singh aptly refer to him simply as “Guruji”!

Sustainable Development Goal Series: Water Science and Sustainability: An Introduction

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Bindhy Wasini Pandey and Subhash Anand

Abstract

Life sustains on the foundation of natural resources and water is one of them, which are essential commodity for the existence of human being and flora and fauna. Any evidence of life cannot be imagined without water. Potentiality of becoming water as critically scarce resource in the coming years is increasing continuously due to various factors. Looking the importance of water from local to global level, its integrated, appropriate and long-term strategies are much needed for sustainable water resource management. Book consists of total 19 chapters on different dimensions of water resources having case studies adopting very relevant and useful methodologies and providing sustainable solutions for the rational utilization and consumptions of natural resources in the various parts of the world. Out of the total case studies, book covered seven case studies from different parts of the world along with 10 chapters from various regions of India. The successful attempt has been made to address all these issues and to create a responsible academic contribution to the field of sustainable water resource management. Scientific study considered as need of the hour for establishing its economic feasibility and technical applicability with the consideration of the eco-hydrological, environmental and social aspects. An in-depth hydrological study is required in the contemporary scenario and strategies are required to be formulated and implemented for maintaining freshwater quality for sustainable future of earth.

Keywords

Water resource · Hydrological · Sustainable solutions · Long-term strategies · Scientific study

Geohistorical evidence says that among the naturally found chemical compounds on this planet, water is the most significant one and it makes this planet unique in the universe known to the human being. Water plays an essential role in the existence of society (Anand et al. 2013). It is the water; in which life originated, took shape and became intricate and diverse with the time. Water determines the formation of biotic communities. Water is the key to the long vividness and the adaptability to survive. Any evidence of life cannot be imagined without water; its mere presence is indicative of life wherever it is found.

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Significance of water has been immense for the development of civilizations (Singh and Pandey 1996b). Importance of water as a resource is indelible across the entire biotic community, including human beings (Igor 1993). Dating back to 5000 years during Indus Valley Civilization, Harappa produces the evidence that people of ancient civilization settled near the sources of water which were used for several (domestic, irrigation, public baths and rituals and other activity) purposes (Singh and Pandey 1993, 1996b). It is still used for almost all religious rituals and ceremonies as offerings to the Almighty God because it is considered as purifying source (Pandey 2004). Due to many reasons; today, the demand and need for water has exceeded the limit of its availability (Nair 2004). In the contemporary scenario, water resource is stressed with accentuating demands to fulfill the requirements and likely to arise in the near future (PAI 1997). It is getting strained due to consistent population pressure, increasing industrialization and rapid growth of urbanization (Gleick et al. 2002). Water degradation requires urgent attention as long with its quality, water quantity is also decreasing at a very rapid pace, hence, suitable inexpensive water treatment and recycling methods are needed for the development in present century together with reuse or conservation methods (Anand 2013). Thus, it should be the prime question to the world's intellectual dais because this is the core element of the factor to survive. The comprehensive, adequate, appropriate and long-term strategies are needed for sustainable water resource management (Agarwal et al. 2000). Its management is required not only for the economic prosperity but also to enhance the quality of life of human beings as well (FAO 2002). Moreover, these management practices should be based on managing the freshwater demand and supply under the stressed water availability conditions and increasing water supply (Cosgrove and Rijsberman 2000; Nolde 2005).

Today, water resource storage, retrieval and dissemination constitute significant monitoring system for sustainable development (Amarasinghe et al. 2007). Water resource availability is adequately enough for its present requirements, whereas geographically its allocation and quality are incredibly varied in quantities (Lal 2001). Precipitation is the main factor of the water cycle for considering the vital element for biome because it can alter and modify the allocation of water resources and also shaped it; while the average annual precipitation of India is estimated about 4000 BCM (Billion Cubic Meter) out of which some part is lost as evapotranspiration, some water gets percolated in the ground as groundwater recharge and the remaining appears as surface water (MoWRRDGR 2019). The water resource potential of India gets flowed as natural runoff in the rivers, and groundwater recharge is estimated at about 1869 BCM (Planning Commission of India 2013). It constitutes a little over 4% of the total river flows of the world (Pandey et al. 2004). However, topographical and climatic constraints allowed only about 1121000 Million Cusec Meters (MCM) freshwater to beneficial use annually worldwide (Suhag 2016). It can be achieved through 690 BCM of utilizable surface water and 431 BCM through groundwater (MoWRRDGR, GoI 2019). A large number of projects, including ongoing projects such as dams, barrages, hydropower structures, canal networks have come all over the country in successive Five-Year Plans (NCIWRD 1999). A milestone in water resources management is the creation of a huge capacity for storage (Rao 1973; Simonovic 2000). Now it has become possible to provide assured irrigation in the command areas and scarce regions of India (Gandhi and Namboodiri 2002).

Nowadays, several hydro and thermal power plants are actively seen in providing services to meet requirements for various uses in the country. Flood moderation and water storage techniques for fulfilling the essential requirements of people and have also been effectively regulated in many flood-prone areas (Seth 2000). Besides this, with the positive and productive approaches to the schemes of the government for drinking water supply in remote and harsh areas has also become possible due to various technological advancements (Allan 1998; Hassing et al. 2009).

This edited book is a compilation of the valuable contributions made by eminent scientists and research scholars, who are trying to develop alternative strategies, solutions and models for sustainable water resources development through various research, monitoring and experiments ranging from regional to global scale. This edition would be of immense use to the policymakers, environmentalists, ecologists, academician and research scholars for water resources management. Chapter 1 of the book is devoted to our Guru (Mentor) Prof. R. B. Singh by Prof. Shouraseni Sen Roy while Chap. 2 discusses the introduction of the book by Bindhy Wasini Pandey and Subhash Anand.

The next chapter (Chap. 3) by Volchak and Parfomuk discusses the runoff of the Neman River Basin in Belarus and Lithuania focusing on climatic factors as well as anthropogenic factor to be responsible for the change in the runoff. Changes in river water runoff for the Neman river basin using two scenarios of economic development and climate change (A1B and B1) were forecasted. The data sources are based on the materials taken from 24 hydrological stations from 1961 till 2009 and 23 meteorological stations from 1961 up to 2010 at the Neman River. They have used Mezentsev's method for the hydrological climatic calculations. They described that the A1B scenario indicates the increase of runoff from 7.4% to 33.9%. Scenario B1 has shown the change in runoff from 1.9% to 21.6%.

Integrated Water Resources Management (IWRM) has increasingly become an essential rallying theme for addressing the governance and management of water resources. They have also discussed how IWRM is perceived in southern Africa and the challenges for applying this concept in water resources governance and management within the region. Using the case study of Zimbabwe; they also have discussed the ongoing debate about the extent to which the implementation of IWRM has succeeded in the country. However, at the grassroots community level, the implementation of IWRM is constrained due to limited choices that these communities have. Due to poverty and impoverishment, these communities depend directly on land-based resources for their livelihood. Many of which lead to environmental degradation, which in turn undermines the availability of water in the environment (Chap. 4, Mukwada et al.).

Salahuddin in her chapter (Chap. 5) on 'urban heat island growth and health hazard in the megacity of Hyderabad' concluded that a linear relationship between the city size and the heat island growth. As Hyderabad has the largest urban sprawl among the Peninsular Indian cities, it has also recorded a considerable daytime and even higher nocturnal transition in the heat island intensity. Nocturnal urban heat island intensity has been recorded higher than the daytime effect. Urban Heat Island prevents the nocturnal radioactive cooling, which renders it more uncomfortable. Chapter 6 by Jana and Mondal on 'Physical environmental impact assessment of flood: A case study of lower Darakeswar-Mundeswari interfluve in West Bengal', discussed flood which is most natural disasters in the humid tropics, especially, in India. It has been estimated that 42.43% of the total area of the state is flood-prone. They have focused on the assessment of the physical environmental impacts of flood in Darakeswar-Mundeswari interfluve in Hugli District of West Bengal. The possible relevant measures toward reducing the magnitude of flood impact have also been suggested. It has been found that the anthropogenic activities such as building activity and eventual urbanization, channel manipulation through the diversion of the course of the river, construction of bridges, barrages and reservoirs, agricultural practices, deforestation, land use changes, etc. are major factors responsible behind the occurrence of flood in the study area.

Chapter 7 by Kirsta and Puzanov analyzed water quality management runoff, which involves mathematical models to assess quantitatively the hydrological and hydrochemical processes in river basins. They have emphasized on the models, which can take into account both temporal and spatial effects of natural and anthropogenic (if any) factors on hydrological and hydrochemical regimes of rivers. They have also discussed about the calculation of the

seasonal runoff where four hydrological periods/seasons were specified: winter low water, spring-summer flood, summer low water and autumn low water. A total of 13 typological geosystem groups (landscapes) were selected to account for a landscape structure of river basins.

The combined models for normalization and spatial generalization of monthly precipitation, temperature and hydro-chemical runoff of river basin of the Altai-Sayan mountain country have been estimated and analyzed in Chap. 8. Aladyshkina (et al.) tried to understand the integrated water resource management, which is a process that promotes the comprehensive development and management of water, land and other resources. This promoted to enhance socioeconomic well-being inclusively without compromising the sustainability of the vital ecosystem. The sharing of water in different regions creates the social conflicts which later concluded with basin agreements. It is concluded only for interregional water objects, i.e., catchment area which is located within several subjects of the Russian Federation. It does not take into account the cross-border nature of water objects located in the territory of one subject of the Russian Federation but covers the boundaries of several administrative areas.

Chapter 9 on 'Water resources of Madhya Pradesh: Contemporary issues and challenges', by Sharma analyzes the regional variation in potential as well as utilization of water resources within the state following variations in hydrogeological aquifers, precipitation pattern, land use and cropping structure. Various issues such as inter-state river water disputes, rapid silting of reservoirs, water pollution; waterlogging and salinization have been addressed. Sergey V. Kholodkevich et al. in Chap. 10 have discussed the quality of the natural water incoming on water intakes of water supply in certain European countries. The uses of high level of chemical in drinking water are danger and economic losses in such cases depend on speed of acceptance of the management decisions directed to their prevention and elimination. They have analyzed that the BioArgus-W is a science-based, multi-parameter, multi-level biomonitoring system comprising several building blocks. Even a failure in one of them can reduce partly or entirely a whole system efficiency. The main distinctive features of the BioArgus-W system are test organisms (crayfish and fish) used as the sensors.

Chapter 11 by Ravi S Singh and Sarah Ahmad elaborated that water is regarded as the ultimate source of life in all the world religions including Hinduism, Christianity, Islam, Judaism and Zoroastrianism and provides a run-through of water symbolism of world religions followed by focusing on the various facets of water in Islam. Water is an essential element for the survival of living creatures on the globe. Our dependency on the water can be seen from the daily chores to economic activities such as agriculture, industries, or public health, safety and recreation. This chapter aims to outline different roles of water in the Islamic teachings and its applicability in today's world for instance, in water conservation.

Chapter 12 by Singh et al. analyzed 'Water resource management through ecological restoration in Garhwal Himalaya, Uttarakhand'. The study focuses on ecological restoration for the water resource management, integration of extreme events, climatic vulnerability, land use land cover (LULC) changes and natural resource for sustainable development planning. It has also been discussed that climate change and anthropogenic activities are continuously disturbing the natural system of the Garhwal Himalaya. Its impact on sustainable development and water potential is clearly visible according to the authors assessment output.

Jana et al. in their Chap. 13 on 'Changing rainfall patterns and their linkage to floods in Bhagirathi-Hooghly Basin, India: Implications for water resource management', have discussed the synoptic view of recent changes in the patterns of rainfall and their linkages to extreme floods in Bhagirathi-Hooghly Basin (BHB). This study provides a better understanding of long-term and short-term trends and variations in rainfall and ascertains whether the extreme floods. The analysis reveals a long-term insignificant declining trend of annual as well

as pre-monsoon rainfall, on the other hand, the increasing trend in monsoon and post-monsoon season over BHB. Rainfall during winter seasons showed a decreasing trend and the changing rainfall trends during monsoon months is a significant concern for rainfed agriculture.

In Chap. 14, Selvakumar and Chandrashekar have focused on the coastal aquifer and impact of mining in southern Tamil Nadu, India. The inland Sand dunes area is the area with no active mining but receiving the impact of mining activity. Hydrological, geochemical and groundwater table characteristics of the shallow coastal aquifer systems, in the mining and non-mining areas, have been investigated to identify the salinization process. The NaCl ratio, correlation matrix and ionic relationship between major ions show a marked increase in salinization in the active mining area. Chapter 15 on 'Flood simulation modeling and disaster risk reduction of West Tripura district, Tripura, North-East India' has been authored by Bhowmick and Das. Both the authors have focused on the impact of the flood, which covers about 40% area and 41% population of the district, including Agartala (the capital of Tripura). They have analyzed flood risk and its reduction modeling done by using flood simulation model for 50 and 100 years return period with 46 years' water level of the HaoraRiver. It is indicating 11 meters above the mean sea level as the highest water level and 8–11 meters above mean sea level for the LoharNala.

Chapter 16 of the book deals with Remote Sensing and GIS Based Morphometric Analysis of Spiti River Basin by Arif Husain and Pankaj Kumar. Three different basins have been delineated by using hydrological tool given in the ArcGIS 10.1. They are named as Spiti, Tsarap Chu and Parechu basins with an area 5419 km^2, 781 km^2 and 651 km^2, respectively. The morphometric parameters of all the three sub-basins have been calculated. ArcGIS 10.1 software was used for delineation and computation of drainage parameters and also for generating map layout. Morphometric analysis of the study area of all three sub-basins represents sub-dendritic to dendritic drainage pattern with moderate to very fine drainage texture. The bifurcation ratio of all three basins indicates normal basin category and the presence of low drainage density suggesting that region has highly permeable sub-soil.

Chapter 17 of the book is contributed by Sahila Salahuddin on 'Demarcation of hyper arid land in the Indian Desert: An Environmental Analysis' concluded that most parts of the Indian Desert are admittedly mild but there are small remote patches, which qualify themselves to be extreme desert. Central Arid Zone Research Institute delineated the semi-arid and arid lands in the Indian Desert. Semi-arid lands depicted a greater half of the desert and arid lands comprised lesser half of the Indian Desert. However, a micro-level analysis of the western frontier of the Indian Desert has revealed a narrow strip of hyper arid conditions in the Indian Desert adjacent to Cholistan Desert in Pakistan. The enquiry reveals meteorological, hydrographic and botanic evidences to this effect. The hyper arid conditions would become even more intense and further challenging in the wake of global and regional climate change.

(Chapter 18) Volchak et al. have described the prediction of the flood evolution is a complicated task, which makes it necessary to take into account a lot of factors. Particularly, long spring flood is typical for water regime of some rivers, having nourishment of a mixed type with prevailing snow one. Snow storage at the beginning of the active melting period is the main source of the maximal discharges causing material and social damage. Besides the amount of snow, weather also makes substantial influence on the spring flood formation. In the last, Chap. 19 presents the concluding remarks of the book by Bindhy Wasini Pandey and Subhash Anand.

The aforesaid chapters of the present book will look into the various issues related to environment in detail. The papers also suggest solutions for the rational utilization of natural resources in different parts of the world. Life sustains on the foundation of natural resources and water is one of the essential natural resources. Potentiality of becoming water as critically scarce resource in the coming years is increasing continuously due to various factors as discussed

above. Fickle climatic characteristics both in time and space are responsible for unequal distribution of precipitation across India. Scientific and technically strengthened structural and non-structural measures are required for mitigating the droughts and floods. Mathematical models and techniques with an enhanced meteorological algorithm are needed for forecasting the monsoon rainfall accurately, which must be utilized by the farmers and decision-makers for adopting appropriate strategies for management of droughts and floods.

Further, there is a need for increasing the availability of water and reducing its demand equipped with better management. Encouragement for better management of existing system and creation of additional storages by constructing large, medium and small-sized dams in consideration with the environmental, economic and social aspects is need of the hour. Rejuvenation of dying lakes, ponds, rivulets and tanks by induced-artificial recharge of groundwater may further enhance the potentiality and availability of water resources. In addition to these measures, inter-basin transfer of water provides one of the best options for mitigating the problems of the surplus and deficit basins. A scientific study needs to be carried out for establishing its economic feasibility and technical applicability with the consideration of the eco-hydrological, environmental and social aspects. Integrated and coordinated development of surface water and groundwater resources and their conjunctive use should work under the bottom-up approach from the project pre-planning stage and should form an integral part of the project implementation. There is a need for proper groundwater resources management, which requires adequate inputs including financial, human resources, technologies etc. Improving public water supply, awareness, use of energy pricing and supply to manage agricultural groundwater reduce the dependency on agriculture and formalizing the water sector are some of the measures for sustainable development of groundwater resource (Rosegrant and Ringler 1999).

Considering anthropogenic changes, an accurate assessment of available surface and the groundwater resources is needed for planning, design and operation for watershed management. Based on logical and scientific techniques, there should be a periodic reassessment of the potential of ground and surface water. Consideration of the cost-benefit approach or quality of water available and the economic viability of its extraction needs to be taken care of. An in-depth hydrological study is required in the contemporary scenario for assessment of water resources under changing climatic scenario. Strategies are required to be formulated and implemented for maintaining freshwater quality.

Adhering toward environmental flow rate, a minimum flow must be maintained in the ecosystem of the river. The eco-hydrological approach based on the green and blue waters concept should be involved as an essential part of the water resources management practices by balancing water between natural availability and human needs. The concept of virtual water transfer in water resource management can be an essential step. Therefore, it needs to be presented on the table of policymakers and academicians. The capacity building and awareness campaign must be prepared for making the masses aware. Serious participation of people in water management practices has to be included. Developing resource morality for making efficient use of water resources has to be instilled in people across all strata. Building capacity for water resources is also needed for managers as well as users and developers for updating and implementing the knowledge and latest technology in the sector of water resources management. The book is an attempt to address all these issues and

to create a responsible academic contribution to the field of sustainable water resource management.

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Forecast Changes in Runoff for the Neman River Basin

3

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Abstract

Changes in river runoff for the Neman River basin using two scenarios of economic development and climate change (A1B and B1) were forecasted. The data sources are based on the materials for the 24 hydrological stations since 1961 till 2009 and 23 meteorological stations since 1961 till 2010 at the Neman River in Belarus and Lithuania. During the research, we devised a multi-factor model based on joint solution of the equations for water and thermal balances. Modeling the water balance was realized in a computer program. The results for the A1B scenario indicate the increasing of runoff from 7.4% to 33.9%. Scenario B1 has shown change in runoff from 1.9% to 21.6%.

Keywords

Runoff · Water · Balance · Model · Forecast · Change · Neman river

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3.1 Introduction

The main hydrological parameters of the river runoff are not stable. These parameters change constantly under the influence of the complex variety of factors. The combination of these factors can be divided into climatic and anthropogenic those differ by the nature and consequences of impact on water resources (Water Resources 2012).

Natural causes determine spatial-temporal variations of water resources under the influence of the annual and secular climatic conditions. Intra-annual fluctuations occur constantly and consistently. Secular variations occur slowly and cover quite extensive areas. These variations are typically quasi-periodic and tend to some constant value. Studies show that in historical time, these deviations were not progressive. Periods of cooling and warming, dry and wet alternating in time and the general condition of water resources and their quality do not change significantly. The main feature of the natural reasons is that the changes have not unilateral tendencies (The Blue Book 1994).

Anthropogenic causes are the result of various human activities. They affect water resources and water quality relatively quickly and unilaterally, and this is their main difference from natural causes. The economic activities causing changes in quantitative and qualitative parameters of water resources are diverse and depend on the

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physiographic conditions of the territory, the characteristics of its water regime and the nature of the use (Water Resources 2012).

The climate change and the increasing of anthropogenous effect on the river runoff during the last 20–30 years are observed. Hydrological regime for the Neman River basin is determined by the natural fluctuations of meteorological elements and anthropogenic factors. In this case, the role of the anthropogenic factors increases every year despite the economic downturn, and inadequate attention to these factors may lead to significant errors in the determination of estimated parameters (Ikonnikov et al. 2003; Volchak and Kirvel 2013).

The aim of our research is the forecasting changes in river runoff for the Neman River basin using two scenarios of economic development and climate change (A1B and B1).

Research performed under the UNDP project 00079039 "Management of the Neman River basin with account of adaptation to climate change".

3.2 Data Sources

The Neman River basin is shown in Fig. 3.1 (Korneev et al. 2014).

The data sources are based on the materials for the 24 hydrological stations at the Neman River in Belarus and Lithuania since 1961 till 2009 (Table 3.1).

The climatic information consisted of the air temperature, precipitation and deficits of air humidity since 1961 till 2010 for 23 meteorological stations were used (Table 3.2).

3.3 Research Methods

For the research purposes, Mezentsev's method of the hydrological-climatic calculations was adapted. The method is based on joint solution of the equations for water and thermal balances (Mezentsev 1995). During the research, we devised a multi-factor model that includes the standard equation of water balance. The developed model is used to assess the possible changes in runoff according to the various hypotheses of climate fluctuations and anthropogenic impacts on water resources.

The equation of water balance is following:

$$H(I) = E(I) + Y_K(I) \pm \Delta W(I), \qquad (1)$$

where $H(I)$—total humidity, mm; E(I)—total evaporation, mm; $Y_K(I)$—total calculated runoff, mm; $\Delta W(I)$—changes of humidity reserves of the active soil layer, mm; I—interval of averaging.

The total evaporation is given by:

$$E(I) = E_m(I)\left[1 + \left(\frac{\frac{E_m(I)}{W_{HB}} + V(I)^{1-r(I)}}{\frac{KX(I)+g(I)}{W_{HB}} + V(I)}\right)^{n(I)}\right]^{-\frac{1}{n(I)}}, \qquad (2)$$

where $E_m(I)$—maximum total evaporation, mm; W_{HB}—minimum humidity ratio of the soil, mm; $V(I) = W(I)/W_{HB}$—relative index of the humidity of soils at the beginning of calculating; $KX(I)$—sum of precipitation, mm; $g(I)$—soil–water balance component, mm; $r(I)$—parameter depending on water physical properties and mechanical composition of soils; $n(I)$—parameter depending on physical–geographical conditions of runoff.

Relative index of the soil humidity at the end of calculation period is determined from the following relations

$$V(I+1) = V(I) \cdot \left(\frac{V_{av}(I)}{V(I)}\right)^{r(I)}; \qquad (3)$$

$$V_{av}(I) = \left(\frac{\frac{KX(I)+g(I)}{W_{HB}} + V(I)}{\frac{E_m(I)}{W_{HB}} + V(I)^{1-r(I)}}\right)^{\frac{1}{r(I)}}. \qquad (4)$$

The values $V_{av}(I)$ are compared with the relative index of the total humidity V_{TH}. If $V_{av}(I)$ V_{TH} then must be taken the calculated value of the relative average humidity, otherwise, when $V_{av}(I) \geq V_{TH}$ then taken $V_{av}(I) = V_{TH}$ and the value $(V_{av}(I)\text{-}V_{TH})\cdot W_{HB}$ refers to surface runoff.

The maximum total evaporation is according to the method described in Volchak (1986).