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Hydrology and Best Practices for Managing Water Resources in Arid and Semi-Arid Lands



Christopher Misati Ondieki and Johnson U. Kitheka

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Hydrology and Best Practices for Managing Water Resources in Arid and Semi-Arid Lands

The management of water resources is extremely important for survival. Depending on the climate, certain regions require different strategies to maintain sustainable hydrological systems.

Hydrology and Best Practices for Managing Water Resources in Arid and Semi-Arid Lands is a crucial scholarly resource that outlines current trends in water management and offers solutions for the future of this growing field. Highlighting pertinent topics such as hydrological processes modelling, satellite hydrology, water pollution, and climate resources, this publication is ideal for environmental engineers, academicians, graduate students, and researchers that are eager to discover more about the issues and processes currently shaping water management technology.

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- Aridity Indices
- Climate Resources
- Drought Management
- Hydrological Processes Modelling
- Hydrometeorology
- Population Dynamics
- Sanitation
- Satellite Hydrology
- Water Agencies
- Water Pollution



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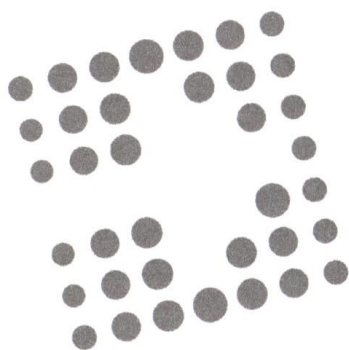
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Foreword

It is now roughly thirty years ago that Christopher (Misati) Ondieki and myself have crossed the Laikipia district in Kenya to gain first insights into the hydrological conditions of this marvelous landscape in the vicinity of Mount Kenya burdened with serious problems related to water shortage in many surrounding regions. The work was done in the framework of the “Laikipia Research Project” of the University of Berne. The Laikipia project dealt with “Water and Land Management”. The authors of the book have a wealth of experience in the arid and semi-arid lands where they have sought to improve the management of the scarce water. In particular they have tried to develop best Practices for Managing Water Resources in the drylands through the studies in catchments in Kenya, Tanzania, Somalia and Namibia.

The book presents concerns of hydrology and water resources in arid and semi-arid lands (ASALs) where conflicts in resource use occurs due to poor knowledge of best practices that could be employed. Water allocation and abstractions have an important impact on the management of river basins undergoing land use/cover changes. The rising populations and climate change pose conflicts of water scarcity which is made worse in drought periods. An improved understanding of the drought events made possible by data sharing, assessment and dissemination to decision makers would be of value to sustainable resource use in the ASALs. This book has made a good attempt towards this purpose.

Food security in ASALs, require adequate water availability. Yet the water resources have challenges ranging from data scarcity and climate change to inefficiency in water use and land use/cover changes over time. Management practices that minimize losses of the limited water have to be achieved by stakeholder involvement, especially through equitable sharing of irrigation water with reduced losses in farms.

This book has discussed problems commonly experienced in arid and semi-arid lands with potential solutions highlighted. Sustainable resource management in

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ASALs can be achieved by considering the approaches provided in the case studies. Concepts on hydrological processes and sustainable management concern many academic disciplines and professionals in industry. There is need for assured decision making for sustainable practices to support livelihoods in ASALs. The contents in this book are therefore useful in research, development and management of river basins in ASAL regions.

Christian Leibundgut

University of Freiburg, Germany

March 7, 2017

Christian Leibundgut is a long serving professor of Hydrology in both Institute of Geography, University of Berne, Switzerland and Institute of Hydrology, University Freiburg, Germany (1988-2008). He has served as Director of the Centre of Water Research (ZWF) of the University of Freiburg. His research topics include, Tracer hydrology, Solute transport, Impacts of land use change on hydrological systems, Runoff generation, Karst hydrology, Hydrology of arid and semiarid zones, Water protection, Water Resources Management, Hydrological maps/atlasses/Information systems, Irrigation and History of Hydrology. In the 80s he had intensive investigations on the hydrological conditions of the Mount Kenya region on problems related to water shortage in the framework of the “Laikipia-project” of the University of Berne. He has had cooperation in various scientific commissions: He was President of the International Association of Tracer hydrology (ATH, 1976-1981), President / Past President of the International Commission on Tracers of IAHS (International Association of Hydrological Sciences), 1991-1997, Secretary 1999-2001, Vice-President of the International Association of Hydrology (IAHS) 2003-2007. He was a member of the Hydrological Commission of the Swiss Academy of Sciences, 1978-90, member of the Working group 5.1 “Hydrological processes in arid and semi-arid zones” of IHP UNESCO, 1997-2002. He was Co-Editor “Hydrological Sciences Journal”, 1993-1999, Co-Editor “Wasser- und Boden”, 1998-2005. 2008-20013 he acted as President of the Swiss National Research Program NRP 61 “Sustainable Water Management.”

Foreword

Arid and Semi Arid Lands (ASALs) is frontier of growing natural resources extraction and socio-economic development. This book has presented the pertinent issues on the hydrology and water resources management in ASALs; issues that often cause resource use conflicts either because they are poorly understood or due to lack of sharing of good practices. The book is divided into three sections. Key issues in ASALs touch on water balance, water allocation and abstractions as well as overall watershed management based on land use/cover changes and their impacts. These issues are well captured in section one which deals with hydrological processes and water allocation and abstractions showing that the various perspectives of the hydrology of ASAL areas revolve around aridity and water security and challenges of measuring the same. These in addition to the impacts of climate change and transboundary nature of water resources hinder comprehensive planning and integrated water resources management. Our understanding of the relationship between stream flow and river water salinity, conductivity and TDS had been heretofore limited. Modeling approaches provide highlights on the importance of maintaining environmental flow as an important factor in equitable distribution of water resources and appropriate irrigation practices. The section concludes with assessment of the hydrologic droughts in the Juba river basin to demonstrate use of hydrological studies on risk management effects on the provision of water for domestic and irrigation use. The study calls for a better approach to irrigation water management through proper irrigation scheduling and sustainable water abstractions.

Solutions to data scarcity, data sharing, modeling and stakeholder engagement for sustainable management have been discussed in section 2. Challenges in ASAL areas worldwide can be pegged to the dominant hydrological processes whose response to the rising populations and climate change in watersheds threaten food security and create conflicts in society. The water scarcity is a critical issue and manifested in the severity of the drought vagaries. The important concern for the future is the availability of water and its efficient use for food security amidst challenges of climate change and land use change. Rainwater harvesting and equitable sharing of irrigation water with reduced losses in farms through collaboration are highlights

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for Best Management Practices that would ensure sustainability. Most approaches benefit from data monitoring and dissemination and improved understanding of process dynamics.

Overall the rest of the chapters describe key global problems and solutions to Water Resources Management and Policy leading to sustainable development in arid and semi arid lands. The editors have put together a valuable volume with useful content. Water resources being central to socio-economic development, this book is a must read for individuals who want to know the critical issues that make for sustainable utilization of ASALs resources. The need to meet current and future challenges in ASALs should be the concern of many professionals in geography, environmental engineering and agriculture as well as decision makers, and other stakeholders with interest in sustainable practices especially in developing countries.

In academic institutions where concepts on hydrological processes and sustainable water resources management are sought through curricula of diverse departments, this book is useful for researchers, educators and practitioners in river basins especially in ASAL areas and it provides potential for conflict resolutions through an integration of best management practices.

George Okoye Krhoda
University of Nairobi, Kenya
March 9, 2017

George Okoye Krhoda is an Associate Professor and the Managing Director of Research on Environment and Development Planning (REDPLAN) Consultants Ltd. Until December 2006, he was the Permanent Secretary, Ministry of Environment and Natural Resources and Chairman of the Negotiation Committee on the Nile Basin Cooperative Framework, and earlier Permanent Secretary in the Ministry of Water and Irrigation where most of the water sector reforms were carried under his watch. Prof. Krhoda is a Hydrologist/Water Scientist and worked for the Government of Kenya, has M.A and Ph.D on river hydraulics and water resources planning. His current research concentrates on hydrology and water resources management, policy dialogue and conflict over use and access to natural resources, institutional reforms, floods and environmental management. Krhoda is a member of Kenya National Academy of Sciences and patron of Hydrological Society of Kenya.

Preface

OVERVIEW

Arid and semi-arid lands (ASAL) are presently undergoing major transformations due to climate change and rapid increase of human population. ASALs are vulnerable environments which often have unsustainable water resources utilization practices. Trend in land use and cover changes lead to water scarcity that impacts the socio-economic livelihoods of people. Research in hydrology is important for determining the available water resources and their utilization. Most of the research is carried out in watersheds where monitoring of hydrological data is collected for instrumented sites. Analyses of the data and use of suitable models could yield information for managing watershed resources for future posterity. Managing the scarce water resources in the ASALs require appropriate practices derived from knowledge of spatial and temporal information on the state of watersheds. The use of GIS and remote sensing techniques is critical in most applications in river basins and these rely on data sharing among users as well as stakeholder involvement.

HYDROLOGY AND WATER RESOURCES TODAY/ OBJECTIVES OF THE BOOK

Hydrology plays a central role in water resources. Hydrologic studies carried out in river basins with special attention to selected semi arid watersheds of Africa are presented with a focus on water resources management in a number of case studies. The pertinent issues include hydrologic modeling, water scarcity, water quality, climate change and stakeholder involvement and hydrologic data management. These are important for integrated water resources management not only in ASAL areas but also in high potential areas now undergoing human induced changes and experiencing the threat of desertification. Good practices in the management of water resources are sought through research and review of documented records of by National agencies and global monitoring systems.

TARGET AUDIENCE

Sustainable water resources planning and management would improve livelihoods in ASALs. The book can be of use among professionals in environmental sciences and engineering. It has value to stakeholders in the business of water and livelihoods in vulnerable ASAL areas. Decision makers in government departments will derive immense benefits based on the need to understand the hydrologic processes affecting water resources availability and how the scarce water resources utilization can be planned appropriately in ASALs. The topical issues in this book are of relevancy in research, academics and postgraduate studies in universities, especially in the developing countries of the tropics. River basin management authorities and water resource management commissions that have to contend with the challenges of degradation of watersheds, water scarcity, conflicts and preservation of ecological integrity of Riverline and coastal systems draining ASAL areas will find this a useful reference text.

BOOK STRUCTURE AND CHAPTER SYNTHESIS

The book structure consists of three sections pertaining to the hydrology and water resources management of ASAL areas. These sections are:

- Section 1:** Hydrological Processes and Water Allocation and Abstractions.
- Section 2:** Hydrological Data Systems and Land Use Change Dynamics and Impacts.
- Section 3:** Water Resources, Management, and Policy.

Section 1: Hydrological Processes and Water Allocation and Abstractions

In Chapter 1, Christopher Ondieki presents perspectives of the hydrology of ASAL areas based on various studies. The areas have been characterized by aridity indices and challenges of water security which include; effects of climate change, transboundary issues and water use conflicts. The study notes the importance of rainwater harvesting and the use of information and sound databases in sustainable resource planning and development for productive ASALs through continuous research and dissemination of results.

Chapter 2 is focused on the understanding of the influence of stream flow variability on water salinity in ASALs paying special attention to the Tiva river basin in Kenya. Johnson Kithika has shown existence of a significant relationship between stream flow and river water salinity, conductivity and TDS and; their inverse correlation

to turbidity. The increase in water salinity of rivers during dry seasons limits the use of water in ASALs. Since upstream irrigation practices can lead to an increase in water salinity thereby limiting crop production, the study notes that construction of dams in ASALs would help to control salinity and promote sustainable irrigation and land use practices.

In Chapter 3, Jacob M. Katuva, Christian T. Omuto and John P. Obiero have carried out a study titled ‘Water Allocation Assessment and Hydrological Simulation on Mukurumudzi River Basin in Kenya.’ The chapter provides highlights on the importance of managing water abstraction in rivers in order to maintain environmental flow. The chapter notes that water abstractions should be managed through issuance of permits for normal and flood flows to ensure consistent water balance without deficits. The authors show that the water deficits in ASAL areas could be compensated by constructing dams and that climate change has to be accounted for by use of holistic watershed modeling that includes groundwater dynamics and water quality.

In Chapter 4, Mwadini Khatib, Joy Obando and Shadrack Murimi have investigated the ‘Effects of Irrigation Management Practices on Water Allocation Among Farmers in Kiladeda Sub-Catchment, Tanzania.’ The chapter shows that inappropriate irrigation practices in upstream areas of ASAL river basins leads to conflicts in downstream. The chapter also shows that irrigation systems such as furrow irrigation and use of plastic buckets are unsustainable in ASALs leading to wastage of scarce water resources. The chapter shows that inappropriate irrigation practices will lead to significant water shortages by 2020. The study calls for a better approach to irrigation water management through proper irrigation scheduling and sustainable water abstractions.

In Chapter 5, Ann N. Njoroge has carried out a study on the hydrologic drought events in Juba River in Somalia. The study notes that hydrologic droughts in the Juba river basin have their underlying causes in the hydrological processes of the basin. The study demonstrates how hydrologic studies can be used to promote drought risk management in ASALs paying special attention to Baardheere Region of Somalia.

Section 2: Hydrological Data Systems and Land Use Change Dynamics and Impacts

In Chapter 6, Jacobine Taukondjele Amutenya and Gerald (Augusto) Corzo Perez present a study titled: ‘Infrastructures for Data in the Context of Flow Forecasting Using Artificial Neural Network Model for Okavango River in Namibia.’ The study has shown that the HydroServer Lite (HSL), a web based data storage system in Namibia Hydrological Services can promote sustainable water resources management in ASALs. Through linkages with to online ANN forecasting model, the system can run using the near real time data to provide continuous forecasts.

In Chapter 7, Luke O. Olang, Mathew Herrnegger, Doris Wimmer and Josef Fürst have presented a study titled: ‘A Spatial Database of Hydrological and Water Resources Information for the Nyangores Watershed of Kenya.’ The chapter has shown that spatial datasets including land cover, geomorphology and soil datasets when processed together with the observed hydrological and topological data, is useful in building a database that can support water resources planning in ASALs. The study notes that the preparation of products such as spatial maps can have application among various players involved in river basin management.

In Chapter 8, Jean-Fiston Mikwa Ngamba, Ewango Corneille Ekokinya, Cush Ngonzo Luwesi, Yves-Dady Botula Kahindo, Muhogwa Jean Marie and Hyppolite Nshimba Seya have presented a study on ‘Multi-Temporal Landsat Remote Sensing for Forest Landscape Fragmentation Analysis in the Yoko Forest, Kisangani, DRC.’ The study has shown that large scale human induced fragmentation in the Congo River basin over the last 40 years is affecting water resources and livelihoods in the Congo Basin. Emphasis has been placed on the need for Integrated Management of Water, Land and Ecosystems.

Section 3: Water Resources, Management, and Policy

In Chapter 9, Samwel N. Marigi has given a contribution on ‘Hydrology and Best Practices for Managing Water Resources in Arid and Semi-Arid Lands.’ The chapter shows that water resources utilization especially for horticulture causes stress in the ASALs due to population pressure and poor resource use and management. The author has indicated that stringent management principles of IWRM are required to ensure sustainable water utilization and further notes the need for determination of vulnerability to climate change and policy interventions.

In Chapter 10, Joy Apiyo Obando, Cush Ngonzo Luwesi, Nele Förch, Anthony Ogutu Opiyo, Chris Shisanya and Gerd Förch have contributed on a topic: ‘Kenya’s Success Story in Water Resources Management: Participatory Capacity Building in Integrated Watershed Management.’ The study points out the importance of political discourse in raising awareness among stakeholders and policy formulation. It emphasizes the need for integrated water resources management (IWRM) and integrated watershed management (IWM) in order to promote coordinated development and management of water, land, and related resources. The findings from this study indicate that IWRM is a key driver for strengthening stakeholder participation and capacity building.

In Chapter 11, Cush Ngonzo Luwesi and Amos Yesutanbul Nkpeebo have presented a study titled: ‘Towards an Integrated Innovative Technologies for Sustainable Provision and Financing of Groundwater in African Drylands.’ The authors have indicated that groundwater development for agriculture has started to

offer incentives for private investors. They foresee potential in integration of ICT with hydraulic technologies to sustain cropping and food production in African drylands by blending the Bhungroo, GrundfosLifelink and M-Pesa (BGM-P) technologies for agricultural groundwater supply to offer incentives for private investors. This paves the pathway for sustainable agricultural intensification in ASAL areas anchored on accessing timely services in right quantities at the right places.

IMPACT OF THE BOOK

This book addresses the role of hydrology in sustainable development of low potential economies of the tropics. Livelihoods must be supported in the face of extreme climate change impacts by improving water resources planning and management as well as ecological health of watersheds undergoing land use change. The chapters are focused on key challenges in planning for sustainable water resources management. The problem of poor data availability, common databases and data sharing opportunities globally are explored using advances in spatial technologies such as remote sensing and model applications in support of sustainable water allocations.