Chapter 1 : Assessment of Water Availability in the Sokoto Rima River Basin

The earth and its physical features / V.I. Babkin --Water resources assessment / V.I. Babkin --Methods for assessing and forecasting global water use and water availability / I.A. Shiklomanov and N.V. Penkova --Water resources, water use and water availability in Europe / I.P. Zaretskaya --Water resources, water use and water availability in.

Kathmandu Valley, Capital city of Nepal. This study applied three hydrological models i. The water balance components were investigated using the same precipitation, climatic data, and potential evapotranspiration PET as input variables for each model. The yearly and seasonal variations in each component and the interactions among them were analyzed. There was a close agreement between the monthly observed and calibrated runoff at the watershed scale, and all the three models captured well the flow patterns for most of the seasons. New hydrological insights for the region: The average annual evapotranspiration ET was , , and mm, and the estimated yearly average total water storage TWS was 5, , and 29 mm, respectively. The long-term average TWS component was similar in all three models. ET had the lowest inter-annual variation and runoff had the greatest inter-annual variation in all models. Predictive analysis using the three models suggested a reasonable range for estimates of runoff, ET, and TWS. Although there was variation in the estimates among the different models, our results indicate a possible range of variation for those values, which is a useful finding for the short- and long-term planning of water resource development projects in the study area. The effects of historical water use, water stress, and climatic projections using multi-model water balance approaches offer a useful direction for future studies to enhance our understanding of anthropogenic effects in the Kathmandu Valley. Evolution of the nexus as a policy and development discourse. The key resources that sustain life and the ecosystem e. Action in one sector might have impacts on others, thus forming a policy nexus among them. The relationships between the resources were realized long back; however, the nexus concept is still evolving as a policy and development discourse with the involvement of many actors. This chapter presents a systematic review on how the nexus concept emerged and is now spreading to cover wider sectors; it then discusses key actors involved in raising the profile of the nexus as a policy and development discourse. The need for the nexus approach. Therefore, the nexus approach integrated policies related to water, energy, and food is required in the face of growing concerns over the future availability and sustainability of these resources. This chapter discusses trends in availability and consumption of the three key resources i.

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Chapter 2 : Climate change impacts on hydrology and water resources of Indian River basin

INTERNATIONAL HYDROLOGY SERIES World Water Resources at the Beginning water use and water availability in Asia 94 V.P. Yunitsyna 6 Water resources, water use.

Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans , evaporation , evapotranspiration and groundwater recharge. Although the only natural input to any surface water system is precipitation within its watershed , the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs , the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All of these factors also affect the proportions of water loss. Human activities can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands. Humans often increase runoff quantities and velocities by paving areas and channelizing the stream flow. The total quantity of water available at any given time is an important consideration. Some human water users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and no water at all in the winter. To supply such a farm with water, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. Nevertheless, over the long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed. Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. It can also be artificially augmented from any of the other sources listed here, however in practice the quantities are negligible. Humans can also cause surface water to be "lost" i. Brazil is estimated to have the largest supply of fresh water in the world, followed by Russia and Canada. For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow. The hyporheic zone often forms a dynamic interface between surface water and groundwater from aquifers, exchanging flow between rivers and aquifers that may be fully charged or depleted. This is especially significant in karst areas where pot-holes and underground rivers are common. Groundwater Relative groundwater travel times in the subsurface Groundwater is fresh water located in the subsurface pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between groundwater that is closely associated with surface water and deep groundwater in an aquifer sometimes called " fossil water ". A shipot is a common water source in Central Ukrainian villages Groundwater can be thought of in the same terms as surface water: The critical difference is that due to its slow rate of turnover, groundwater storage is generally much larger in volume compared to inputs than it is for surface water. This difference makes it easy for humans to use groundwater unsustainably for a long time without severe consequences. Nevertheless, over the long term the average rate of seepage above a groundwater source is the upper bound for average consumption of water from that source. The natural input to groundwater is seepage from surface water. The natural outputs from groundwater are springs and seepage to the oceans. If the surface water source is also subject to substantial evaporation, a groundwater source may become saline. This situation can occur naturally under endorheic bodies of water, or artificially under irrigated farmland. In coastal areas, human use of a groundwater source may cause the direction of seepage to ocean to reverse which can also cause soil salinization. Humans can also cause groundwater to be "lost" i. Humans can increase the input to a groundwater source by building reservoirs or detention ponds. Frozen water Iceberg near Newfoundland Several schemes have been proposed to make use of icebergs as a water source, however to date this has only been done for research purposes. Glacier runoff is considered to be surface water. The Himalayas, which are often called "The Roof of the World", contain some of the most extensive and rough high altitude areas on Earth as well as the greatest area of glaciers and permafrost outside of the poles. To complicate matters, temperatures there are rising more rapidly than the global average. In Nepal, the temperature has risen by 0. Desalination Desalination is an artificial process by which saline water generally sea water is converted to fresh water. The most common desalination processes are distillation and reverse osmosis. Desalination is currently expensive compared to most alternative sources of water, and only a very small fraction of total human use is satisfied by desalination. It is usually only economically practical for high-valued uses such as household and industrial uses in arid areas. However, there is growth in desalination for agricultural use, and highly populated areas such as Singapore or California. To produce food for the now over 7 billion people who inhabit the planet today requires the water that would fill a canal ten metres deep, metres wide and kilometres long. Increasing water scarcity See also: Water scarcity in Africa Around fifty years ago, the common perception was that water was an infinite resource. At that time, there were fewer than half the current number of people on the planet. People were not as wealthy as today, consumed fewer calories and ate less meat, so less water was needed to produce their food. They required a third of the volume of water we presently take from rivers. Today, the competition for water resources is much more intense. This is because there are now seven billion people on the planet, their consumption of water-thirsty meat and vegetables is rising, and there is increasing competition for water from industry , urbanisation biofuel crops, and water reliant food items. An assessment of water management in agriculture sector was conducted in by the International Water Management Institute in Sri Lanka to see if the world had sufficient water to provide food for its growing population. To avoid a global water crisis, farmers will have to strive to increase productivity to meet growing demands for food, while industry and cities find ways to use water more efficiently. Various irrigation methods involve different trade-offs between crop yield, water consumption and capital cost of equipment and structures. Irrigation methods such as furrow and overhead sprinkler irrigation are usually less expensive but are also typically less efficient, because much of the water evaporates, runs off or drains below the root zone. Other irrigation methods considered to be more efficient include drip or trickle irrigation , surge irrigation , and some types of sprinkler systems where the sprinklers are operated near ground level. These types of systems, while more expensive, usually offer greater potential to minimize runoff, drainage and evaporation. Any system that is improperly managed can be wasteful, all methods have the potential for high efficiencies under suitable conditions, appropriate irrigation timing and management. Some issues that are often insufficiently considered are salinization of groundwater and contaminant accumulation leading to water quality declines. As global populations grow, and as demand for food increases in a world with a fixed water supply, there are efforts under way to learn how to produce more food with less water, through improvements in irrigation [11] methods [12] and technologies , agricultural water management , crop types, and water monitoring. Aquaculture is a small but growing agricultural use of water. Freshwater commercial fisheries may also be considered as agricultural uses of water, but have generally been assigned a lower priority than irrigation see Aral Sea and Pyramid Lake. Water withdrawal can be very high for certain industries, but consumption is generally much lower than that of agriculture. Water is used in renewable power generation. Hydroelectric power derives energy from the force of water flowing downhill, driving a turbine connected to a generator. This hydroelectricity is a low-cost, non-polluting, renewable energy source. Significantly, hydroelectric power can also be used for load following unlike most renewable energy sources which are intermittent. Ultimately, the energy in a hydroelectric powerplant is supplied by the sun. Heat from the sun evaporates water, which condenses as rain in higher altitudes and flows downhill. Pumped-storage hydroelectric plants also exist, which use grid electricity to pump water uphill when demand is low, and use the stored water to produce electricity when demand is high. Hydroelectric power plants generally require the creation of a large artificial lake. Evaporation from this lake is higher than evaporation from a river due to the larger surface area exposed to the elements, resulting in much higher water consumption. The process of driving water through the turbine and tunnels or pipes also briefly removes this water from the natural environment, creating water withdrawal. The impact of this withdrawal on wildlife varies greatly depending on the design of the powerplant. Pressurized water is used in water blasting and water jet cutters. Also, very high pressure water guns are used for precise cutting. It works very well, is relatively safe, and is not harmful to the environment. It is also used in the cooling of machinery to prevent overheating, or prevent saw blades from overheating. This is generally a very small source of water consumption relative to other uses. Water is also used in many large scale industrial processes, such as thermoelectric power production, oil refining, fertilizer production and other chemical plant use, and natural gas extraction from shale rock. Discharge of untreated water from industrial uses is pollution. Pollution includes discharged solutes chemical pollution and increased water temperature thermal pollution. Industry requires pure water for many applications and utilizes a variety of purification techniques both in water supply and discharge. Most of this pure water is generated on site, either from natural freshwater or from municipal grey water. Industrial consumption of water is generally much lower than withdrawal, due to laws requiring industrial grey water to be treated and returned to the environment. Thermoelectric power plants using cooling towers have high consumption, nearly equal to their withdrawal, as most of the withdrawn water is evaporated as part of the cooling process. The withdrawal, however, is lower than in once-through cooling systems. Basic domestic water requirements have been estimated by Peter Gleick at around 50 liters per person per day, excluding water for gardens. Drinking water is water that is of sufficiently high quality so that it can be consumed or used without risk of immediate or long term harm. Such water is commonly called potable water. In most developed countries, the water supplied to domestic, commerce and industry is all of drinking water standard even though only a very small proportion is actually consumed or used in food preparation. Recreation Whitewater rapids Sustainable management of water resources including provision of safe and reliable supplies for drinking water and irrigation, adequate sanitation, protection of aquatic ecosystems, and flood protection poses enormous challenges in many parts of the world. Recreational water use is usually a very small but growing percentage of total water use. Recreational water use is mostly tied to reservoirs. If a reservoir is kept fuller than it would otherwise be for recreation, then the water retained could be categorized as recreational usage. Release of water from a few reservoirs is also timed to enhance whitewater boating, which also could be considered a recreational usage. Other examples are anglers, water skiers, nature enthusiasts and swimmers. Recreational usage is usually non-consumptive.

Chapter 3 : Water Resources

To provide a modern assessment of the state of the world's water resources, this text develops a uniform methodological approach for each continent to analyze the dynamics of water resources, water use and water availability worldwide.

Nineteen smaller catchments contribute the remaining water mainly from annual precipitation. The latter will gain importance if glaciers retreat as predicted. Hydrological models can visualize such climate change impacts on water resources. However, poor data availability often hampers simulating the contributions of smaller catchments. Monte Carlo simulations were used to define parameter uncertainties and ensembles of behavioral model runs. Model performances were evaluated by constrained measures of goodness-of-fit criteria cumulative bias, coefficient of determination, model efficiency coefficients NSE for high flow and log-transformed flow. The developed data pre-processing arrangement can utilize data of relatively poor quality only monthly means or daily data with gaps but still provide model results with NSE between 0. Some of these may not be accurate enough to directly guide water management applications. However, the pre-processing supports producing key information that may initiate rigging of monitoring facilities, and enable water management to respond to fundamentally changing water availability. However, large amounts of water are stored in glaciers, permafrost and snow on high mountain ridges in Kyrgyzstan and Tajikistan in the East of Central Asia. At present, these water storages play the key role in the water management that has to regulate the supply for the livelihood in the Central Asian lowlands including main parts of the Ferghana valley in Uzbekistan Figure 1 , The valley floor at about m is surrounded by the mountain ranges of the Tien Shan and the Alay mountain systems that reach up to m a. These orographic conditions protect the valley against the invasion of cold air masses from the north but open it to relatively moist air from the west [3 , 6 , 7]. Therefore, the Ferghana Valley has relatively warm winters and hot summers [8]. As the moist air from the west is forced to move upwards, which includes adiabatic cooling, the precipitation generally increases with elevation and reaches up to mm per year at the northwestern slopes of the Ferghana ridge [8 , 9]. The Karadarya and Naryn rivers have their source in the eastern part of the Ferghana Valley and the Tien Shan mountain system in Kyrgyzstan, from where during summer they are mainly fed by glaciers and snow melt. Smaller streams and catchments at the proximate northern, eastern and southern ridges around Ferghana Valley contribute water mainly from annual rain and snowfall and only a few streams to the south include some glacial melt. Based on the analysis of observed climatic data of Central Asia for the 20th century, air temperatures are increasing especially in the lowlands and during winter months [11]. The total area covered by glaciers in Kyrgyzstan decreased from km2 in to km2 at around and further to km2 in [13]. The Tien Shan glaciers alone showed a reduction of Finally, many authors assume that the rate of glacial melt in Central Asia has accelerated since the s [4 , 15 , 16]. According to [17], the future changes in precipitation, glacial melt, groundwater extraction, reservoir construction, and population growth will involve only a moderate risk of water shortage in the Syrdarya River basin. In contrast, the IPCC emphasized with very high confidence that Central Asia is under high water stress, and that water resources are extremely vulnerable to climate change [12]. Accordingly, the further decrease of glaciers will most likely lead to runoff changes from the Naryn and Karadarya rivers. The volume of water discharged into the major rivers of the region may increase in the short-term but decrease over the long-term. Thus, the contributions of small, mainly precipitation-driven catchments may become more important for the water balance of the Ferghana Valley in coming decades. As the people in the region depend on irrigated agriculture, it is of significant interest to assess the contribution of the small upper-catchments under current conditions, and to simulate the future runoff dynamics [18 , 19].

Chapter 4 : WHO | Publications on water sanitation and health

Water resources, water use and water availability in Europe / I.P. Zaretskaya 5. Water resources, water use and water availability in Asia / V.P. Yunitsyna.

Besides climatic change, current demographic trends, economic development and related land use changes have direct impact on increasing demand for freshwater resources. Taken together, the net effect of these supply and demand changes is affecting the vulnerability of water resources. In this study, we review the evolution of approaches to vulnerability assessment related to water resources. From the current practices, we identify research gaps, and approaches to overcome these gaps a generalized assessment framework is developed. The results of the feasibility study identify the current main constraints e. The results of this study can be helpful for innovative research and management initiatives and the described framework can be widely used as a guideline for the vulnerability assessment of water resources systems, particularly in developing countries. Introduction Freshwater systems are part of larger ecosystems which sustain life and all social and economic processes. The provision of freshwater is therefore an ecosystem service which, when disrupted, threatens both the health of ecological systems and human wellbeing, which are in complex interaction [1]. Scientists within the Intergovernmental Panel on Climate Change IPCC expect that the present increase in greenhouse gas concentrations will have direct first-order effects on the global hydrological cycle, with impacts on water availability and demand [3]. These changes will in turn create other higher order effects [4], which are shown in Figure 1. Overall at the global level, a net negative impact on water availability and on the health of freshwater ecosystems is foreseen [5], and thus a cascade of negative consequences is expected to affect social and ecological systems and their processes. Different order climate change effects on water resources. Besides climate, there are other drivers of change, such as increased population pressure, economic development and urbanization trends. These drivers of change are closely linked to each other and pose complex management problems for land and water resources. As populations grow and move to citiesâ€”and as their income levels increase or decreaseâ€”their demand for water resources changes both spatially and temporally. Taken together, the net effects of these supply and demand changes in areas of increasing population, can translate into increases in the vulnerability of water resources systems, which can create major challenges for future management of water resources for human and ecosystem needs. As stated above, climate change can contribute further to exacerbate problems, in particular when considering medium to long term projected impacts. There is therefore a need to assess the vulnerability of water resources systems for enhanced management strategies, also including robust adaptation measures for future sustainable water use. Vulnerability assessment is not straightforward, in particular because there is no universally accepted concept for vulnerability. For example, Thywissen [6] lists 35 definitions of the term. The plurality of the definitions leads, as expected, to very diverse assessment frameworks and methods [7 , 8 , 9 , 10 , 11 , 12 , 13]. Some authors even argue that by principle, vulnerability cannot be measured as it does not denote observable phenomena [14 , 15] while, according to [16] the opportunity arises to make this theoretical concept operational. Indicators can provide the means for doing so and, in particular, make the assessment of vulnerability possible, as we propose herein with the methodological framework for the assessment of the vulnerability of water resources, within the broader context of climate change adaptation, and with a specific emphasis on operational implementation in developing countries. Water resources systems are complex in nature and consist of four inter-linked sub-systems: As a consequence, management issues should generally consider multiple decisional criteria and large numbers of possible alternatives, usually characterized by high uncertainty, complex interactions, and conflicting interests of multiple stakeholders, but also of a multiplicity of compartments, such as river, land or coastal ecosystems, or different economic sectors [18]. Due to this dual complexity i. The issue of vulnerability was first brought to the attention of policy makers in an international context in the field of water resources management in at the Dublin Conference [19] Dublin

Principle 1 states that fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment. Later, several studies on the vulnerability assessment of water resources systems were carried out at various geographical scales, e. A few studies e. In some of these studies [20 , 23 , 26], vulnerability is considered only as a physical component of water resources and these studies focus on water resources availability rather than how society and the ecosystem deal with water [28]. Global and large scale studies usually cannot provide the detailed information that is required for appropriate adaptation and management actions [27]. Other studies [22 , 25 , 27 , 28] incorporate important components i. Similarly, a society cannot improve without the support of innovative scientific ideas and technical knowledge. Given the above, the specific objective of this study is to propose a generalized framework for scientifically based vulnerability assessment to support participatory decision making processes in the field of water resources management WRM , with a specific interest for climate change adaptation CCA. In developing such a framework, the following section reviews the most recent international literature, while the framework itself is described in Section 3. Section 4 introduces the Lower Brahmaputra River Basin LBRB , the case study utilized for preliminary feasibility analysis of the proposed approach with its potential implementation on the LBRB area and discusses the results of a survey with local experts and stakeholders. Finally, Section 5 concludes the results discussing the operationalization of the framework and the experiences in the study case and identifies future research needs. Vulnerability Assessment Models and Frameworks 2. Birkman [30] provides an overview of the evolution of the different spheres of widening vulnerability concepts evolving from intrinsic risk factors to a much broader multidimensional concept, encompassing physical, social, economic, environmental and institutional features. Within such broader vision, different schools of thought have developed and some of them are of specific interest here: The assessment of vulnerability is intrinsically linked to the notion of these different schools of thought. Each of these conceptual approaches can lead to the formulation of diverse policies. As a consequence, Eakin et al. The DRR school of thought was established in s and views disasters as having socio-economic and political origins [38 , 39]. Later, it considered the wider social, political, environmental and economic dimensions of hazards [40]. More recently, CCA policy negotiations have started considering ways to reduce vulnerability to the expected impacts of climate change. Although the DRR and CCA communities have both been engaged in reducing socio-economic vulnerability to natural hazards, they have given different definitions and conceptualizations of the same terminology [40 , 41 , 42]. For example, the conceptualization of vulnerability by the DRR community [43] is different from the conceptualization by the CCA community [44]. Hinkel [16] criticizes the definition of the IPCC as being too vague and the resulting difficulty in making it operational. However, the definition provided by the IPCC is one of the most generic available, and thus it could be considered as a basis for further refinement, such as was the case of the global environmental change and sustainability science communities, who introduced the notion of the coupled social-ecological system SES , also referred to as human-environment system, in conceptualizing vulnerability [10]. We follow the IPCC definition of vulnerability for the purpose of this research. Notwithstanding the terminology problems, there is an evident and urgent need for vulnerability assessment of coupled systems for adaptation to the foreseeable consequences of climate change [42]. In climate change adaptation, vulnerability assessment for the future is considered as the forward-looking aspects of vulnerability. Hinkel [16] states that forward looking aspects are one of the most important characteristics of vulnerability and their incorporation in the assessment is one of the most challenging tasks. Indeed a forward-looking approach should be considered as a prerequisite for any study targeting adaptation to climate change. According to [13], for climate change vulnerability assessment, more specifications are required and at least four fundamental dimensions should be incorporated in the assessment, i. The system of analysis is typically a coupled social-ecological system, a population group, an economic sector, a geographical region, or a natural system, and the examples of attributes of concern may include human lives and health, the existence, income and cultural identity of a community, or the biodiversity, carbon sequestration potential and timber productivity of a forest ecosystem. Hazards can be related to climatic variables, such as extreme rainfall events and the consequent flood risk. The temporal reference when dealing with the CCA typically considers a rather wide future time frame, long enough to appreciate the effects or expected changes of climatic variables. According to these four dimensions, the assessment context for our research could thus be defined as: System View in Water Resources Management and Decision Making Considering water resources systems WRS , individuals, organizations and society can be considered as a social system which is nested within an ecological system [17]. Therefore, it is the complex interactions of the social-ecological system that make decision making more and more difficult in the WRS and the traditional fragmented approach of water management has to be replaced by more holistic system view approaches [46]. Integrated Water Resources Management IWRM is such an approach that has been widely accepted internationally as the way forward for efficient and equitable management of water resources. According to this approach, water managers inform the initial steps of the decision-making process and participate in planning the appropriate responses, interacting with the principal actors policy makers and with the managers of other sectors. Water managers address the demands of water users to meet the life-sustaining requirements of people social dimension and the needs of other species ecological dimension and to create and support livelihoods, by implementing an iterative and adaptive participatory process. Although IWRM is considered by a majority of scientists and experts as useful theoretical framework, it is now openly debated whether it is truly effective in terms of operational implementation. The IWRM approach can nevertheless provide an opportunity for the development of a method for vulnerability assessment, which thus becomes one of the main components of the process to manage water resources with a holistic approach targeting the whole WRS. Indices for the Assessment of Vulnerability of Water Resources With the aim of providing quantitative assessment of vulnerability, several indices have been proposed in the field of water resources. Very often, vulnerability assessment of water resources incorporates only physical components consisting, for example, of water scarcity calculations using the water scarcity index which can be defined as the ratio of water demanded to the supplied volumes. Following this index, a number of studies have been carried out at the global scale [20 , 49 , 50 , 51 , 52 , 53]. However, annual level assessment of water scarcity does not incorporate the fact of inter-annual seasonality. For example, large parts of monsoon Asia suffer from severe water scarcity in dry periods while the average annual resource availability appears to be plentiful. With a more holistic system view of water resources, several recent studies [21 , 22 , 25 , 27 , 29] have conducted vulnerability assessment and proposed other concise indices. In this assessment, WSI was calculated from the aggregation of four water stress parameters e. Considering social, economic, environmental and physical components, Balica et al. In the assessment, aggregation of the parameters between water stress and water variation, water exploitation and safe drinking water inaccessibility, water pollution and ecosystem deterioration, water use efficiency, improved sanitation accessibility and conflict management capacity represents RS, DP, ES and MC respectively. The vulnerability index VI is calculated by aggregating four vulnerability components with equal weights given to the parameters, as shown in Equation 1. The indicators and the variables that are considered in these studies were not selected with the involvement of local stakeholders. However, it is necessary to investigate local perceptions in order to identify appropriate indicators that can play an important role for effective decision making. Very recently, Sullivan [24] developed a water vulnerability index WVI , in which indicators were identified by local stakeholders in municipalities in the South African portion of Orange River Basin. The WVI is calculated based on two major dimensions: From the above review, we can summarize some conceptual gaps. Firstly, the lack of consideration of forward-looking aspects or future aspects is one of the main shortcomings of vulnerability assessment in general, and vulnerability assessment of water resources systems in particular. Secondly, instead of annual level assessment of water scarcity, seasonal variations reflecting water abundance and scarcity regimes should be considered. Thirdly, for vulnerability assessment of water resources systems, it is necessary to move from static usually cartographic indexes i. Fourthly, vulnerability assessment should be accomplished through involving stakeholders. Proposed Framework of Vulnerability Assessment for Water Resources System In order to overcome the conceptual gaps identified in

Section 2 , we propose and describe a logical sequence of steps for vulnerability assessment of water resources systems which is shown in Figure 2. In the following description, each step of Figure 2 is represented by letter, aâ€”n. For example, step 1 identify key stakeholders is shown as Figure 2 a.

Chapter 5 : Scientific Facts on Water Resources

Australia's water resources and use Table Origin of distributed water by state and territory, and This includes water supply, sewerage and drainage industry only (excludes water provided by other industries).

The projection of many studies has confirmed that in next years the earth will experience with high surface temperature. However, the modification in the global hydrological cycle due to climate change, drought, flood, changes in rainfall pattern, extreme weather events and alteration in river flow and groundwater recharge Fig. Additionally, climate change has already impacted on the various mega-deltas particularly due to sea-level rise and changes in runoff3. It is estimated that around million people live in the 40 mega-deltas globally. However, the mega-deltas including the Ganges-Brahmaputra in Bangladesh, the Mekong in Vietnam and the Nile in Egypt are most vulnerable deltas of world Fig. The rising surface temperature of the Indian subcontinent by 0. These reports indicate that climate change has largely influenced the water resources of the Indian subcontinent. However, in developing country like India, water demand for various sectors such as domestic, industrial and agricultural uses, has already increased in last few decades. Therefore, present study is based on the given expected changes due to climate change over the Indian River basins and has been reviewed with studying the topography of river basin, water availability, climatic and hydrological condition. In this study, we have tried to summarise the previous studies related to Ganges-Brahmaputra-Meghna GBM river basins keeping in view that how the climate has changed in these river basins in recent times. Indian River Basin In India, Himalayan range is the greatest source of pure water in the form of snow that melts and transverses through 45, km long riverine networks. Additionally, various Indian river basins are experiencing with minimal per capita water availability which is mainly due to considerable spatial variation in rainfall. Ganga River associated with some tributaries play an important role in the formation of most fertile alluvial plain. Furthermore, a study reported by Nepal revealed that the highest increase rate of temperature 0. The maximum temperature trends have been observed in Nepal Central Himalayan region The projected future model showed that the annual temperature of this region would increase about 0. The Brahmaputra River Basin The Brahmaputra River also originates from the Himalaya Kailash ranges which transverses east through the southern part of China and enter into eastern India and lastly joins with the River Ganga in Bangladesh. The length of the Brahmaputra River is about km with having a total area of 5, 80, square kilometre. In the upper part of Brahmaputra River discharge mostly comes from the snowmelt before it enters Arunachal Pradesh. However, after it enters into the Indian states of Arunachal Pradesh, Assam, and Meghalaya, river experiences with heavy rainfall which contributes substantially to the river flow. Consequently, river basin experiences with alteration in flow transport of sediment and channel configuration. Some previous studies revealed that the average annual temperature of Brahmaputra basin has increased notably in last few decades. They expected that the temperature might increase from 1.

Chapter 6 : Water resources - Wikipedia

S.K. Jain, V.P. Singh, in Developments in Water Science, River basin planning for water resources development and management has been practiced in many parts of Asia and Africa for at least nine thousand years.

Introduction Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The intergovernmental panel on climate change IPCC developed the variation of the earth temperature for the past years. As climatic variability intensifies, changes in atmospheric conditions have altered water resources, their distribution in space and time, the hydrological cycle of water bodies, water quantity and, in more recent time, water supply systems and requirements for water resources in the Sokoto-Rima river basin, creating serious water shortages for household needs, agriculture and industry. With further significant variations in the climate of the Sahel being predicted by General Circulation Models GCMs IPCC, , it is important that scientific studies be undertaken at regional levels so as to provide society with accurate information on the real and potential impacts of climate change, as well as, the mitigation and adaptation options available. Ekpoh and Ekpenyong, The Sokoto-Rima River basin is located at north western part of Nigeria and it covers four 4 states i. This makes the rivers and streams within the basin to be the important source of surface water to the people living in those states. Therefore, even small decrease in runoff within the basin could have dramatic effects on the water supply of the region. To address this need, this study evaluates the impact of climate change on available water resources in the six main rivers of the Sokoto-Rima river basin using a decision support system known as the Water Evaluation and Planning WEAP Model. WEAP is an analytical framework developed for the evaluation of climate change and other drivers that water managers commonly confront Yates et. Indeed, WEAP model is one of the useful tools for the integrated water resources management and it can be used as a database for the forecasting and also as a policy analysis tool, depending on the focus of the study. In this regard, the applicability of WEAP in assessing the impact of climate change as well as its main function of the sophisticated water allocation model is tested in this study. Statement of the Problem According to Ringiuset, et. A similar idea is also highlighted by Houghton who stated that the most important impact of global warming is on water supplies which are in any case becoming increasingly critical in many places. In the continent of Africa, the observational records show that the climate has been warming through the 20th century at the rate of about 0. In contrast to the assessment of global or large scale variations of the climate driving forces for global hydrology, the impact of climate change on the regional hydrology is still unknown for most regions of the world Kim et. Although climate change is a global phenomenon, the trends and impact may be different on a local scale. Aims and Objectives of the Study The aim is to analyse how sensitive is the Sokoto-Rima River basin to climatic change with regards to its water availability by developing a Model of the basin using WEAP, and propose some mitigation measures that can minimize the negative impact within the basin by the principle of mass balance of the hydrologic quantity of the whole area. While the objectives are: Sokoto-Rima River Basins in Nigeria 2. The area covers a land area of approximately , km2 and shares its borders with Niger Republic to the north, and covers Sokoto, Kebbi, Zamfara and large part of Katsina States to the East; it also borders Niger State to the South-east, and Benin Republic to the west. The whole basin can be described as Sudan and Sahel Savanna, and it extends beyond the border to Niger republic and the northern part of Benin Republic. The basin topography consists of a vast floodplain fadama land and rich alluvial soils that is suitable for the cultivation of different variety of crops. There are also isolated hills inselberg and hill ranges scattered all over the area Ekpoh and Ekpenyong, Rainfall is generally low. The average annual rainfall for 35 years is about mm. Much of the rain falls between the month of may to September, while the rainless months are October to April. Evaporation is high ranging from 80mm in July to about mm in April to May. The hottest months of April to May are periods of highest evaporation. Relative humidity is low most of the year and only increases during the wet seasons of June to September. The vegetation is typically Sudan savannah and is characterised by stunted and thorny shrubs, invariably of the acacia species. Description of Climate of the Basin Like the rest of West Africa, the climate of the region is controlled largely by the two dominant air masses affecting the sub-region. These are the dry, dusty, tropical- continental cT air mass which originates from the Sahara region , and the warm, tropical- maritime mT air mass which originates from the Atlantic Ocean. The influence of both air masses on the region is determined largely by the movement of the Inter-Tropical Convergence Zone ITCZ , a zone representing the surface demarcation between the two air masses. The interplay of these two air masses gives rise to two distinct seasons within the sub-region. The wet season is associated with the tropical maritime air mass, while the dry season is a product of the tropical continental air mass. The influence and intensity of the wet season decreases from the West African coast northwards. In terms of climatic statistics, the annual rainfall for Sokoto ranges between mm and mm. The mean annual temperature is Ekpoh and Ekponyong, 2. Description of Hydrology of the Basin The basin is essentially drained by the river Sokoto, a prominent part of Niger river drainage system. The sokoto river rises with its main tributaries, the Ka, Zamfara, and Rima from the to meters high Mashika and Dunia highland areas bordering the eastern part of the basin, and flows down, rather sluggishly down a gentle slope toward the northwest, where around Sokoto town, it is joined by the Rima in the north, making a southward swing, collecting the Zamfara and Ka before entering in to the river Niger. The river systems, thus effectively drains the whole basin. At the source areas in the east, the Sokoto river system is only seasonal. However in the western parts of the basin, the river becomes perennial as it begins to receive substantial ground water contribution to its flow. Description of Land Use and Land Cover of the Basin The land use and land cover within the basin are grouped in to five major categories: Agricultural land is divided in to three categories: Description Demography of the Basin In , the population in the states of Katsina, Kebbi, Sokoto, and Zamfara total to 10,, people, and consists of Urban and rural population. While the total population according to census for those states total to 16,, people, as shown in table 2 below. The whole states within the basin have an average inter census growth rate of 3. The Bakolori Dam is in Zamfara state, it was completed in and its reservoir filled by Operation of the Goronyo and Bakolori Dams Table 4. It was completed in and commissioned in The dam is a sand-fill structure with a height of 21 m and a total length of It has a storage capacity of million cubic meters. The dam is controlling floods and releasing water in the dry season for the planned Zauro polder project downstream in Kebbi state. Other large dams within the basin are Gusau dam with height of 22m and total length of m located in Zamfara state and Zuru dam with height of 15m and total length of m located in Kebbi state. There are also some small dams within the basin which include Zurmi, Marina and Shagari dams. Materials and Methods 3. Materials The Materials used for this research are: Large flow Current Meter for measurement of velocity of flow in the river and determination of discharge, in using it a thread was used to determine a straight cross section line and divide the cross-section in to equal area and a measuring tape was used for measuring distances. Internet used for research. Methods A water allocation modeling approach is adopted for this study. First the model is applied to determine the surface water resources availability for the current situation and under the future changes of climate. Secondly, the model is used to analyse the linkage between the water resources and the demand in each region or local government based on the population changes in the whole basin. The monthly average rainfall data, the monthly average hydraulic data and the climatic data which include Monthly average temperature for identified major data stations in the sub-catchments for the period of â€" was obtained from the following data stations: The hydrological and hydraulic data obtained and the parameters of a hydrological model in the study area will be used in soil moisture method of Rainfall runoff to generate current stream flows as the model of available water in the area. Climate is assumed uniform over each sub-catchment, and the water balance is given as: Hypothetical climate change scenarios The preferred methods in projecting future scenarios are usually those derived from GCMs GlobalClimatic Models but their limitations of grid-point predictions make them very difficult to adapt to the regional analysis. Nevertheless, use of hypothetical scenario is another option used by researchers in climatic impact studies Islam et. Many published works were done in this way e. From this perspective and aiming to the main objective of the study to assess the applicability of WEAP as a decision support system DSS for climate impact assessment on a river basin, the hypothetical scenario was chosen to generate scenarios. Development of Weap Model For the analyses of hydrological processes in the sokoto-rima river basin, all natural hydrological watershed details and infrastructure for water resources management are represented in the WEAP model. The schematic representation is shown in figure 2 below: Analysis of Climate Change Impact on Water Availability The final stage is to quantify the water availability in all scenarios from the simulation of the model. The water availability within the catchments was evaluated based on the following output of the WEAP model: Total available water within the catchment under a scenario â€” The total water demand within the catchment The water availability in each scenarios then being analysed in order to evaluate the sensitivity of the study area to climate change based on the relation: Water Year Method Figure 3. A single variation fraction is specified for an entire water year type and for all the proposed scenarios. The sensitivity to climate change was explored by defining six scenarios. The reference scenario was adopted using the Water Year Method to reproduce the observed variation in hydrology from the historical record. The remaining scenarios were adopted using the first as a starting point, but altering each water year type according to predicted effects of climate change i. The model simulation was assessed against observed stream flow data for gauges located at some stations within the basin. The data of to was used to set up the model and validated with the streamflow data of to The model was also calibrated with average coefficient of determination R2 of 0. After calibration the model was validated with the actual measurement of streamflow at ten various points on the rivers within the basin. Based on the simulation and comparison of the sreamflow within the basin for the reference scenario and scenarios 1 to 6, it was observed that the effect of the climate change is not uniform. The difference in water availability from the scenarios depends on the section of the stream observed. As shown in figure 6 below, the difference in water volume from the reference scenario to the worst scenario scenario 6 at river Bunsuru is not much but on reaching the river Rima the difference is around Billion Cubic Metres in 44 years simulation, indicating a reduction of 8. Streamflow for the basin Figure 5. Streamflow below river sokoto for all scenarios Figure 6. Streamflow at Bunsuru for Reference scenarios Streamflow for all seven rivers and their different nodes and reaches sections simulated for the period of 44 years are shown in figure 7 below. Streamflow for all scenarios In summary, the model performance is good and reasonable when considering a larger part of the basin figure 8. The results of water availability could be indirectly obtained from the model output. Streamflow for all scenarios Inflow and outflow In order to quantify how much is the water availability within the study area the average reservoirs storage volumes were also determined as shown in figure 9. Average monthly reservoir storage volumes Monthly inflow and outflow from the two dams to downstream are also determined as shown in figure 10 below: Reservoir inflow and outflow The monthly average reservoir storage volume for all scenarios is shown in figure 11 below: Average reservoir storage volume for all scenarios Table 7 shows the different amount of water availability based on the simulation due to different prescribed climate scenarios.

Chapter 7 : VISHNU PANDEY :: IWMI

Poor water quality and unsustainable use of water resources can limit the economic development of a country, harm health and affect livelihoods. On a positive note, more sustainable practices are starting to be adopted.

Chapter 8 : Water Availability and Use Science Program

The USGS works with partners to monitor, assess, conduct targeted research, and deliver information on a wide range of water resources and conditions including streamflow, groundwater, water quality, and wateruse and availability.