Strategy for water resources management in relation to climate change impacts and adaptations

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Abstract Water resources management in some countries has led to fragmented and uncoordinated development and management of water resources. Hence there is need to formulate a strategy which should promote coordinated development and management of water , and related resources in order to adapt to climate change impacts on economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems. Fluctuations in water resources availability which is associated with climate change is a concern , as many regions experience increasingly severe flooding and droughts. Conflicts and competition for the scarce water is a problem which is encountered at various levels of development and stakeholders have difficulty in reconciling the needs of biodiversity , amenity and in-stream benefits. Problems associated with sectoral water resources management are being exacerbated by climate change impacts and this calls for integrated water resources management. There is increasing pressure on the available water resources in many regions and this has impact on the per capita quantity available and also lowering water quality during dry weather periods . To balance water supply and demand, there is need to understand the impacts of climate change and the necessary required adaptations and hence the need for the formulation of relevant strategies. Potential implications of climate change impacts and adaptations on water resources on aspects related to the magnitude , frequency , and timing of precipitation and runoff events , water demand patterns are being significant, hence the need to promote integration of climate change impacts and adaptations in water policy reforms and adaptive planning of water resources. In this paper , the rationale of strategy of integrated water resources management in relation to climate change impacts and adaptations and with respect to sectors of the economy which are vulnerable to water shortages has been explained. Also the functions water resources allocation , pollution control , monitoring , stakeholder participation , economic and financial management , information management , river basin planning and flood and drought management which are essential for effective management of the water resources in a river basin are highlighted and they can be useful tools for managers of water resources in river basins where changes have been caused by direct human interventions and climate change. Hence a sound functional approach is required for sustainable water resources management under nonstationary environmental conditions. In the paper , water resources management performance progress indicators) have also been explained.

Keywords climate change impacts; climate adaptation; water scarce regions; integrated water resources management; economic sustainability; intelligent adaptations; real time challenges; water resources management performance indicators

INTRODUCTION AND BACKGROUND INFORMATION

Climate change and variability has a potential impact on the dynamics of vital ecosystems which when affected end up affecting the sustainable development and management of the water resources in them . In this paper, an integrated rapport between integrated water resources management (IWRM) and climate change has been explained .The dissemination of weather and climate information at the appropriate period can be a useful tool in sustainable water resources management. Climate can have impact on the quantity and quality of water in any region. For any species to survive in any environment there has to be water which is a function of the climatic

characteristics and hence there is need for both plant and animal species to adapt to climate changes if they have to survive and all sectors of the economy has to adapt to climate change .

Essential activities including water resources management and agriculture are affected by recurrent climate change . Variations in climatic patterns, which occur naturally from year to year and over longer periods of time can cause disasters such as droughts and floods and end up affecting millions of people. Such climatic patterns affect the availability of water which is required for social and economic activities on different scales of time and space. The amount of water available for domestic use, agriculture, industry and generating hydroelectricity can be affected by small changes in one of the elements of climate, that is temperature. Warmer temperatures are likely to increase rainfall in some regions while in others there is decrease in rainfall. This will end up in having regional disparities in the amount of rainfall and water. Changes in temperature, rainfall and soil moisture could severely reduce agricultural productivity of marginal lands and hence the need for integrated water resources management.

Drought, crop failure and floods due to climatic change may drive millions of people from their homes, creating unprecedented problems as environmental refugees try to find new area in which to settle. Reduced rainfall amounts may reduce the availability of water, which then can result to complex environmental problems related to water shortages in a given river basin . As a result of climatic impact on water resources this has a potential impact on many sectors of the economy and hence this necessitates the application of integrated water resources management in which all sectors which require water are considered in a holistic manner at all time scales.

Climate change affect human society when it affects water resources for water is the foundation for a fertile environment and underpins most human activities such as social and economic development. As a result of differences in climate characteristics in regions in the world, this has caused water to be distributed unevenly over the planet earth, and is not always available where it is most needed, and this has been a limiting factor in economic development in many countries.

There is evidence that the world's growing population is increasing pressure on the available water supply systems, reducing the per capita water quantities available and lowering water quality. The problems of water quality and quantity can be more severe during dry weather periods for the amount of water in hydrosystems can be very much reduced and hence affect the natural assimilative capacity of such hydrosystems resulting to high concentration of water pollutants which might be persistence and hence the need to apply IWRM.

REAL-TIME CHALLENGES IN WATER RESOURCES MANAGEMENT

The worlds freshwater resources are under increasing pressure . Some of the causes of the pressure on water resources are population explosion ,increased economic activities and improved living standards leading to increased competition for water and conflicts over the limited freshwater resources. A combination of social inequity , economic marginalization and lack of poverty alleviation programmes in many developing countries also force people living in extreme poverty to exploit water

resources by not practicing conservation measures. In regions where there is no effective pollution control measures, this degrades water resources. Other problems are population under water stress, pollution impact , water governance crisis and poor water management due to unsound strategies.

The main challenges which are being faced by many countries Kenya included are securing water for all people , securing water for food production, developing other job creating activities which require water , not protecting vital ecosystems, dealing with variability of water in time and space, managing risks which are climatic in nature or due to land mismanagement , creating popular awareness and understanding in order to mobilize effective support for sustainable water management and induce the changes in behaviour and action required to achieve this, forging the political will to act and ensuring collaboration across sectors of the economy and trans-boundaries . These problems can be mitigated by applying integrated water resources management. Climate change has major impact on the world's freshwater water resources water quality and water management. Increases in water temperature and changes in the timing and amount of runoff are likely to produce unfavorable changes in surface water quality , which will in turn affect human and ecosystem health. The threats posed by climate change will serve as an additional stressor to many already degraded systems , particularly those in developing countries.

INTELLIGENT ADAPTATION TO CLIMATE CHANGE

Integrated water resources management is an intelligent strategy which need to be applied so as to be able to adapt to climate change. Better water resources management is essential if communities are to adapt successfully to climate induced changes in their water resources utilization . The strategies adopted has to use a combination of infrastructural and institutional measures . Water resources users to adapt to climate change require major changes in the way they use water in agriculture , industry and human settlements . Hence the best approach to manage the impact of climate on water is that guided by the philosophy and methodology of integrated water resources management(IWRM).

The IWRM if fully implemented at the national level in all river basins in a country , is expected to promote a holistic approach to water resources management and under IWRM there are multiple pathways to building resilience to water shortages. There is need to identify and to achieve tradeoffs between different water management objectives including environmental sustainability , economic efficiency and social equity . The IWRM approach encourages the structured engagement of real-time stakeholders and sectors impacted upon by water into its management both to seek and promote "win-win" solutions but also to ensure that a better understanding of water constraints and challenges is developed and diffused into the society within a given river basin.
To cope with climate change and be able to adapt to it, countries should have both infrastructural and institutional strategies and it is these strategies which can offer countries the best chance of coping successfully with climate variability and change .

There is need for communities to build resilience to manage the impact of variable climates on human activities and especially those affected by water shortages. Composite rainwater harvesting can enable the households and communities to manage variability of the water resources on which they depend on many activities. Large water infrastructures should be designed so as to operate under the expected climates of the 22nd century and hence the need for climatic models which has long memory for accurate prediction of the dynamics of the temperature future profiles..

Real - time implementation of integrated water resources management if applied in river basins can offer a set of institutional and infrastructural tools to ensure that IWRM works effectively. To address potential water shortages much attention should be given to managing water demand than to increasing supply and this can be done by introducing more efficient technologies as well as simply promoting a culture of conservation. An important element of water demand management is to encourage water users to use the water they have more efficiently.

One way to manage the impact of climate's variability on water resources is to capture and control river flows. Reservoirs can retain and store river flows in excess of user requirements and release them when low flows are not sufficient.; this can also help maintain aquatic ecosystems. Peak flood flows can be stored and released later , avoiding flood damage by reducing maximum flows . These two functions are important and they can sustain human settlements and avert disasters caused by floods and droughts. Other important water infrastructure includes canals , tunnels and pipelines that serve not just to supply human demands directly but also , by creating linked systems with multiple sources , and the stakeholders will suffer less due to water shortages and hence offer enhanced water supply security.

Intelligent institutions are required to coordinate responses and support decision makers in making difficult decisions. There is need to orient water managers in the key water use sectors , to the potential impacts of the emerging new climates. Intelligent institutions are needed that can go beyond managing water on a day to day basis to identify water use trends , areas vulnerable to climate change and opportunities to respond as best as possible to the emerging challenges. There is need to encourage artificial recharge of groundwater aquifers in the arid and semi arid regions by using flood waters and this can be an effective strategy for both sustainable flood and drought management.

There are multiple challenges confronting communities and countries that seek to "climate proof " themselves , in the sense of increasing their resilience to the effects of climate change , by managing their water resources more intelligently. As always the case , poorer countries are expected to face greater challenges and to address them will require strong and well informed leadership as well as effective strategies. In sustainable water quality management some of the strategies which can be applied in water quality solutions are but not limited to the following: pollution prevention, water treatment , wastewater treatment, and the application of ecological restoration and ecohydrology within catchments. Some of the mechanisms to achieve water quality solutions are education and awareness building, mentoring and data collection and also governance and regulation.

SECTORAL IMPACT OF WATER SHORTAGES

Climate change has a potential impact on water resources and this result to impact on the various sectors of the economy. Water shortages could be due to the effect of drought which could be as a result of the impact of dry climate and also due to poor strategies on water conservation in a given river basin . Drought which is a climate anomaly means less water for industry, domestic use and the general environment. The types of industries affected during periods of water shortages are : Agriculture (crops and animals); Fisheries; Hydroelectricity but generally drought has a potential impact on all sectors of the economy if there are no strategies for drought management in a river basin .

When industries are affected due to water shortage which is as a result of climate change and variability , then the following can result lower production levels; Rising prices of commodities; Reduced income levels; Shortages of food and the end result is poor living standards of the civil society. The following domestic type of water use are affected ; water for drinking,water for washing; water for cooking; water for sanitation. As a result of the above problems associated with domestic water use, this can result to health and social problems in society. The problems which are due to the effect of drought on water can result to the following:-Social unrest;Conflict between water users at a local/national level;Population migration;Eventual death of living organisms hence affecting biodiversity which is a good indicator of environmental quality and security.

Any significant reduction in volume of water in lakes, rivers and aquifers during prolonged dry climatic conditions affects water quality and effectively increasing the concentration of any pollutants discharged into the water and this results to high cost in water treatment.

STRATEGIES FOR MANAGEMENT OF WATER SUPPLY SYSTEMS IN DRY CLIMATIC CONDITIONS

Water supply is used for social and economic activities and should be managed optimally during dry weather periods by using the following strategies: Water supply oriented management strategies; Water demand oriented management strategies There is need for accurate information on the prevailing dry weather conditions which should be disseminated at the right time and at the right place. The strategies should be practiced in any water supply system within a given river catchment so as to avoid severe environmental problems associated with water shortages.

There is always a relationship between water shortages in given region and climate parameters. In order to manage water supply systems during periods of dry climatic conditions the following strategies which should be applied: Better use of existing supplies; Inter-basin and within basin transfers and exchange of water supply.; Improving existing supplies; Development of new supplies.

To manage water demand during periods of dry climatic conditions there is need to introduce best management practices and active strategies. Demand oriented measures for water shortage control should be directed toward making the existing inadequate water supply, whatever it may be serve water users as effectively as possible and in a sustainable manner. Applying the active strategies, the following should be practiced to control water shortages during periods of dry climatic conditions: Legal restrictions and public pressures,Economic incentives for reduced water use. For sustainable utilization of water resources of in a region there should be statutory limitations imposed by existing laws of water rights.

STRATEGIC FUNCTIONS , OBJECTIVES AND PROGRESS INDICATORS FOR SUSTAINABLE WATER RESOURCES MANAGEMENT

For sustainable water resources management with the overall objective of adaptation to climate change and impacts there is need to apply a functional approach in catchment management strategy. The functions which can be tried at the catchment level are as follows: water allocation , pollution control, economic and financial management, information management, stakeholder participation, river basin planning, flood and drought management and monitoring. For each of the functions there is need to have progress indicators developed for the specific catchment. Table 1 gives a summary of the required functions for sustainable water resources management while table 2a&b shows a more detailed information on minimum indicators which can be useful tools for sustainable water resources management. in the 21st century. The information shown in tables 1 and 2a and 2b can help in analyzing the trend in sustainable water resources management but more specifically to integrated water resources management at the national , regional and local levels.

Strategic functions	Requirements
Water allocation	Allocating water to major water users and uses . maintaining minimum levels for social and environmental use while addressing

	equity and development needs of the society
Pollution control	Managing pollution using pollute pays principles and appropriate incentives to reduce most important pollution problems and minimise environmental and social impact.
Economic and financial management	Applying economic and financial tools for cost recovery and behavior change to support the goals of equitable access and sustainable benefits to society from water use.
Information management	Provide essential information necessary to make informed and transparent decisions for development and sustainable management of water resources in the basin
Stake holder participation	Implement stakeholder participation as a basis for decision making that takes into account the best interests of society and the environment in the development and use of water resources in the basin
Basin planning	Prepare and regularly update the basin plan incorporating stakeholder views on development and management priorities for the basin , and using it to inform the annual work plans of the river basin
Flood and drought management	Operating floods and drought to mitigate and minimize harm to humans , environment and economic values.
Monitoring	Implement effective monitoring systems that provide essential management data and identify and respond to infringements of law , regulations and permits

Table 1: Strategic functions and their requirements

Table 2: Strategic **f**unctions and water management objectives

SNO	**Strategic functions**	**Water Management Objectives**

1	Water allocation	Major water users are known and are managed through a licensing system.
		Water allocation is in line with sustainable use , economic efficiency and social equity principles .
2	Pollution control	The extent of the pollution problem is known and progress being measured
		Major polluters are known and are managed through a licensing (0r permit) system
3	Economic and financial management	Water use efficiency improving through use of economic and financial instruments
		Pollution reducing through use of economic and financial instruments
4	Information management	Essential data is processed and packaged as information at the right level for specific managers and stakeholders to support transparent decision making and to gain commitment and political support for the decisions made
5	Stakeholder participation	Effective cooperation between government agencies with responsibilities for water management or water use in the basin
		Stakeholder participation is institutionalised in the management of the river basin
6	Basin planning	Basin planning synthesis technical and social priorities for the basin and acts as a basis for action and accountability to the stakeholders
7	Flood and drought management	Knowledge of inundation areas for different flood magnitudes
		Functioning flood warning system
		Functioning drought warning system
8	Monitoring	The water allocation system is effective and permits are being complied with
		The pollution control system is effective and permits are being complied with
		Knowledge of water resources availability is a basis for management

Table 3: Water management objectives and progress indicators .

SNO	Water Management Objectives	Progress Indicators
1	Major water users are known and are managed through a licensing system.	Number of surface and groundwater users licensed according to the regulation
	Water allocation is in line with sustainable use , economic efficiency and social equity principles .	Water allocation criteria include use efficiency , economic benefit and social goals
		% of time environmental and social reserve is maintained in major water courses
2	The extent of the pollution problem is known and progress being measured	% of surface water quality samples complying with water quality objectives
		% of groundwater samples complying with water quality objectives
	Major polluters are known and are managed	Number of polluters licensed according to the

	through a licensing (0r permit) system	regulations
3	Water use efficiency improving through use of economic and financial instruments	Charges and fees for water allocation favour the poor and promote efficient water use
		Bill collection ratio
	Pollution reducing through use of economic and financial instruments	Pollution charges give incentive to reduce pollution
		Bill collection ratio
4	Essential data is processed and packaged as information at the right level for specific managers and stakeholders to support transparent decision making and to gain commitment and political support for the decisions made	Data base established in formats compatible with other river basin organizations
		Water management information is available to managers and other stakeholders as required.
5	Effective cooperation between government agencies with responsibilities for water management or water use in the basin	Number of meetings of Government agencies with water interests to consult and collaborate on water management
	Stakeholder participation is institutionalised in the management of the river basin	Formal stakeholders structures established with clear roles and responsibilities in water resources management
		Basin stakeholders represented in decision making bodies at all levels
6	Basin planning synthesis technical and social priorities for the basin and acts as a basis for action and accountability to the stakeholders	Water management activities driven by basin plan
		Stakeholders priorities reflected in the basin plan
7	Knowledge of inundation areas for different flood magnitudes	Length of river analysed for flood inundation (flood frequency, hydraulic studies and topographical surveys
	Functioning flood warning system	Number of forecasts or warning issued for flood
	Functioning drought warning system	Number of forecasts or warning issued for low flows
8	The water allocation system is effective and permits are being complied with	Proportion of water allocation permit holders complying with permit conditions
	The pollution control system is effective and permits are being complied with	Proportion of water pollution permit holders complying with permit conditions
	Knowledge of water resources availability is a basis for management	Number of water resource monitoring stations producing reliable data
		Total water storage capacity
		% groundwater monitoring stations with declining water levels

MOVING FORWARD IN WATER RESOURCES MANAGEMENT

At the global scale, there is clear need for a coherent approach to water resources management to address the challenges of climate change and obvious potential for an IWRM approach to help meet this need as well as to contribute to the

broader goal of sustainable development. There is need to implement policies that can help in reducing the impacts of climate change on society and the dynamics of ecosystems : The policies should include the following : developing emergency and disaster preparedness policies and programmes ; assessing areas at risk from sea – level rise and developing plans to reduce the vulnerability of costal populations, developments and ecosystems to future climate change; improving the efficiency of natural resource use to minimize climate change impacts on the various sectors of the economy due to water shortages. Hence integrated water resources management is a useful strategy in mitigating climate change impacts on water resources.

An important early step is to work at regional and national level to so as to ensure that all stakeholders are helped to understand the specific local challenges of climate change for their water management and the IWRM planning process in countries should provide a foundation for this engagement.

CONCLUSIONS AND RECOMMENDATIONS

It can be concluded by saying that there is need for effective disseminations of weather and climatic information in both developed and developing countries and especially in developing countries where there is high demand for water and integrated water resources management can be a useful tool to assist in industrial development which eventually can be used as a tool for poverty eradication and hence improve living condition for the society.
During the last decade , Kenya had a problems in hydropower rationing which was as a result of water shortages which was due to prolonged dry spell of weather . With application of integrated water resources management , such problems can be mitigated.

Awareness should be created to the members of the public so that they can know the relationship between water during dry weather periods so that environmental problems associated with water shortages are mitigated. Drought, which is as a result of, dry weather and climatic conditions which results to water shortages is one of the most pervasive and worrisome problems faced by water resources managers.
Drought is complex hydrological phenomena, and embodies issues related to climate dynamics , land use , water use norms, as well as management issues such as drought preparedness.

The commonly held notion of water resources is that which means the whole of the water can be used for supporting the needs of man domestic water and for other socio-economic activities such as food production, forestry, energy, industry, transport, human health and recreation. Some however argue that for water to be a resource, it must be at the time and place it is required and that its availability is only one input into water resources systems management .
In order to mitigate the impacts of climate change with the objective of adaption , to implement integrated water resources management in river drainage basins, the following strategies should be practiced: Integration of freshwater management and coastal zone management; Integration of land and water management ; Integration of surface water and groundwater management; Integration of quantity and quality in water resources management; Integration of upstream and downstream water related

interests in ecosystems ; Integration of all stakeholders in the planning and decision making process. Cross sectoral integration in national policy development.

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