EPRA International Journal of Agriculture and Rural Economic Research
Impact Factor(SJIF) : 4.434 | Volume : 4 | October - September | 2016-17 | ISSN : 2321 - 7847

RESEARCH METHODS TO ASSESS THE IMPACT OF CLIMATE CHANGE ON WATER RESOURCES

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ABSTRACT

The impacts of climate change on water availability and water quality can affect many sectors, including energy production, infrastructure, human health, agriculture, and ecosystems. This paper deals with research methods to study the impact of climate change on water resources. It outlines the application of expert Judgment method, analogue models, predictive models, process based models, assessment of autonomous and planned adaptation, socioeconomic impacts, assessment of water demand impacts, demand under climate change conditions, economic assessment methods and assessment of autonomous and planned adaptation towards studying the impact of climate change on water resources. This paper concludes with some interesting findings along with policy suggestions.

KEYWORDS: *climate change, water resources, energy production, infrastructure, human health, agriculture,*

INTRODUCTION

There are uncertainties about the local and regional impacts of climate change on water resources and uncertain future water demands driven by socio-economic change. It could be noted that an assessment of climate change impacts on water resources is a complex process. In addressing the sensitivity of water resources to changes in climate, the biophysical and socio-economic conditions must be considered. The assessment of climate change impacts on the water resources of a country is the first and most important assessment to be carried out because a wide range of modeling tools allows for a quantitative analysis of climate change impacts, and hydrologic resources are the key component of the entire water resources sector with respect to aquatic ecosystems, water quality, water use, and water management are all based on the hydrologic resources of a country.

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HYDROLOGIC RESOURCES IMPACTS ASSESSMENT

Techniques to assess impacts on hydrologic resources are available for all spatial and temporal scales of analysis and for all levels of local data availability. Four methods for assessing impacts on hydrologic resources are described: expert judgement, analogue methods, predictive models, and process-based models.

EXPERT JUDGEMENT

In terms of assessing climate change impacts on hydrologic resources, expert judgement has a very limited role. Given the data availability and expertise in water resources, it is likely that for all but the smallest budgets some quantitative modelling of hydrologic resources could be performed. Expert judgement is a valuable tool in assessing impacts on water quality, aquatic ecosystems, water demand, and water management systems. In applying expert judgement, the user should be aware that experts may have difficulty in estimating the consequences of events that have not been experienced and may not be able to provide estimates with sufficient accuracy for decision making.

Analogue Methods:-

Examination of past extreme events is useful for showing how systems actually were affected by climate variation and how they responded. It could be seen that Campos and Sanchez (1995), used past El Niño events as an analogue climate change scenario for Costa Rica and Panama. This study found important decreases in reservoir storage, reduction in power generation, and an increase in fossil fuel burning for electricity generation. The problem with analogue scenarios is that greenhouse gas induced climate change is likely to differ from past events, and care should be taken in finding and using appropriate analogues.

Predictive Models:-

Predictive models are based on empirical and statistical relationships. It can be used for quick and low cost assessments. However, because these models do not account for physical thresholds, the process-based models are most appropriate for water resources impact assessments. Many of the predictive models are based on a fundamental theorem in hydrologic theory that was first developed by Dooge (1992). This theorem suggests that when looking at the long-term water balance of a large catchment or region, an appropriate assumption is that the change in storage is zero. Dooge (1992) points out that any estimate of the impact of climate change on water resources depends on the ability to relate change in actual evapotranspiration to estimated changes in precipitation and potential evapotranspiration. Thus, annual average statistical values of a watershed have been used to develop models that can estimate impacts to water resources. Two annual models are a model developed by Turc (1954), which relates precipitation and temperature to runoff, and a model developed by Oldekop which relates precipitation, evapotranspiration, and potential evapotranspiration to runoff.

Process-Based Models:-

Process-based hydrologic models are a class of numerical models used to describe the response of watersheds to climatic inputs. Although the available models vary in precision, they all fall within the acceptable level of accuracy for estimating climate change impacts. Yates et al. (1997) compared hydrologic assessment techniques ranging from simple to complex and found that they estimate the same magnitude and direction of impacts. Methodologies for modelling hydrologic processes were identified by Todini (1988). In increasing order of data needs, these classifications are stochastic, lumped integral, distributed integral, and distributed differential models.

The stochastic modelling approach centers on developing relationships that describe an output variable like runoff in terms of input variables such as precipitation and temperature, without prescribing the physical processes that occur. Lumped integral models are physically based models that normally use the fewest number of parameters that can describe a basin's response to climatological events. These models are designed to look at medium-to-large watershed areas and are often referred to as water balance models. These models are not usually applicable to event-scale processes of daily or hourly precipitation events, but are used after uniformly lumping a sequence of events of precipitation and runoff to monthly mean values. The catchment or sub-catchment is modelled as a single, homogenous unit subject to uniform events and parameters. Parameters for this model type usually are not meant to represent physical catchment characteristics. These models can incorporate interannual variability by accounting for changes in catchment storage. The common link in most water balance approaches is the computation of a mass balance within the soil moisture zone. It is evident from the works of Shaw (1983) Chow et al., (1988) and Rawls et al., (1993) that there are many ways of representing the infiltration, discharge, and storage behaviour of the soil moisture zone. Dooge (1992) Yates and Strzepek, (1994) shown that some basins are quite sensitive to the estimation of potential evapotranspiration, so an accurate representation of this variable is important. There are two major sources of water pollution: non-point sources of agriculture runoff and point sources of municipal and industrial discharges. Climate change could have significant impacts on non-point source pollution from agriculture. In addition, cooling water discharges could be affected by changes in temperature and streamflow. However, climate change should have little impact on per capita or per industrial unit pollution from municipal and industrial sources.

A wide variety of water quality models, in terms of both water quality constituents and level of detail, are available. Some of these models include simple conservative dilution models, simple dissolved oxygen models, detailed dissolved oxygen models with the nitrogen and phosphorus cycles modelled toxics models, and advective diffusion models for temperature, dissolved oxygen, nutrients with nitrogen and phosphorus, algae/periphyton / macrophytes, and pH. For non-point source pollutants, there are area- and model-based methods for estimating pollutant loadings to receiving waters. Simple area-based loadings can be used as inputs to river and lake/ reservoir water quality models. Where data and resources exist, models of non-point source loadings can be used, and adaptations can also be evaluated. Chapra (1996) provides a detailed background of water quality modeling and simplified tools of analysis.

Aquatic Ecosystem Impacts Assessment model:-

The aquatic ecosystem is complex, and assessment of this system will most likely depend on the construction of predictive models. Freshwater ecosystems contain flora and fauna such as algae, periphyton, and macrophytes residing directly in the water, and these are affected by water quantity and quality. Models of these systems are sometimes considered water quality models and many exist. Assessing impacts on other aspects of the aquatic ecosystem such as fish, waterfowl, and wildlife that depend on water quality and quantity requires integration with biological assessment methods that have been developed for other sectors such as biodiversity and fisheries. The results of a hydrologic assessment are often required as inputs for these other sectoral assessments. For example, fish are sensitive to water temperature and dissolved oxygen contents. Thus, modelling the climate change impacts on these parameters provides the necessary information for assessing impacts to fisheries.

SOCIOECONOMIC IMPACTS

The methodologies and modelling approaches presented here span a wide range of spatial and temporal scales. There is no single model appropriate for all socio-economic assessments of climate change impacts. Different approaches provide different insights. Care must be taken to understand the strengths and weaknesses of the approach being used and to identify the appropriate policy questions that it will be used to answer. The selection of an approach will depend on the particular impact of concern of job losses, changes in economic growth, relative growth of different sectors over time and the particular question being addressed are there any significant interactions between sectors as climate changes. The approach should always be selected based on the question of interest. As with the biophysical methods, the choices to be made in method selection depends on the hydroclimatic conditions, the water resource modelling expertise, data availability, and the resources dedicated to the water resources assessment.

ASSESSMENT OF WATER DEMAND IMPACTS

When addressing climate change impacts on water demand, one is faced with two major questions:

- What will the water demand be under future baseline conditions?
- How will climate change affect that baseline scenario?

In many respects, determining the impact of warmer temperatures and changes in precipitation on water demand is more straightforward than estimating? Water demand 50 to 100 years in the future. Water demand is a function of population growth, economic growth, and technological change.

It will be very difficult within the scope of a climate change assessment to do more than a simple –statistical- approach to estimate water use:

DEMAND UNDER CLIMATE CHANGE CONDITIONS

Climate change may affect water use in five water use sectors: agricultural, industrial, energy, municipal, and reservoir losses. Water use for agriculture includes irrigation and livestock water. Changes in irrigation and livestock water use due to changes in temperature and precipitation can be estimated using climate change impact assessment methods for these sectors. Alternatively, irrigation water use can be estimated by using the appropriate reference crop or crops and a potential evapotranspiration model. Irrigation water is used to make up the difference between crop water requirements and precipitation. Thus, irrigation water use will be the difference between actual evapotranspiration and the new precipitation estimates. Livestock water use can best be estimated from the literature for livestock water use versus climate data. If direct statistical relationships do not exist, then a spatial analogue approach is suggested i.e., find a location with current hydroclimatic conditions that are analogous to those forecast for the river basin of interest under climate change and use the per head water use values.

Industrial:-

Temperature and precipitation have little direct impact on the water use of most industries. Falkenmark, (1997) notes that reduction of flow in rivers due to climate change may put increased pressure on waste treatment processes, leading to increased water recycling and a decline in industrial water use.

Energy:-

Water use for energy production takes two forms: hydroelectric and thermoelectric. Reduced flow will reduce hydropower reservoir storage and thus reduce potential energy production. Warmer temperatures will increase evaporation from reservoirs, so more stream flow will be required to maintain the same hydropower energy production. Increased temperature has little direct effect on thermal efficiency; however, increased river temperature and reduced flow can cause cooling discharges to violate environmental standards.

Municipal:-

Kindler and Russell (1984) observed that residential water use is inversely correlated with rainfall and positively correlated with average temperature. Little work has been completed on the impact of long-term climate change on domestic water use. Most analyses to date have drawn information from the response of domestic water users to short-term droughts or warm periods. However, the user must be careful when selecting an analogue approach for domestic water use because climate alone is not sufficient to determine an analogue. Similar socio-economic indicators income and household size as well as climatic variables must be used in selecting analogues since, as stated above; domestic water use is correlated with these socio-economic indicators. In addition, short-term responses of water use could be much different than responses to the prospect of permanent water restrictions and possible lifestyle changes.

Reservoir Losses:-

Increased temperatures lead to increased evaporation, with all other meteorological variables held constant. The increase in reservoir losses to evaporation can be estimated using standard depth evaporation estimates, which are based on estimates of lake or reservoir surface areas. Surface area is a function of reservoir geometry and volume. The volume is a function of inflow runoff and outflow releases; therefore, demand and supply for reservoir water must be analysed to quantitatively measure the impact of climate change on reservoir losses to evaporation. Total water demand is the summation over all water use sectors. The estimate of total demand will reflect potential increases or decreases caused by climate change without any adaptation. In assessing impacts, it is important to clearly identify the level of impact associated with three alternatives: no adaptation, an assumed level of autonomous adaptation, and planned adaptations.

Economic Assessment Methods:-

Strzepek et al. (1996) discusses economic tools for use in climate change assessment. A variety of analytical methods can be used to assess the economic impacts of climate change. Each method has strengths and weaknesses, and each provides different insights useful to decision makers. Any single impact assessment may contain elements of one or more of these methods. Most available models can be categorised as either macroeconomic or sectoral models.

Vaux and Howitt (1984) and Hurd et al., (1998) have examined the economic consequences of climate impacts as related to water resources. Typically, the studies have taken a partial equilibrium sectoral approach, examining the effects in a single market or a group of closely related markets. However, because of complex interdependencies among even seemingly unrelated markets, partial equilibrium analyses can yield potentially misleading results for evaluating broad, economy-wide effects. The potential for error is exacerbated when there are direct impacts on multiple sectors. For example, changes in temperature and precipitation may have a direct impact on the availability of water and on water markets. This direct impact can have indirect effects on markets that rely on the availability of water and are themselves directly affected by climate change such as agriculture, forestry, and electricity supply. A partial equilibrium analysis will typically not account for all of the potential indirect effects. An aggregation of results from partial equilibrium analyses of the separate effects will neglect potentially important interdependencies. In contrast, a macroeconomic analysis is internally consistent. The consistency of sectoral forecasts with realistic projections of economic growth is ensured since they are estimated within the context of a single model. However, the ability to model an entire economy is accomplished at the sacrifice of potentially valuable sectoral detail. For many river basin-level analyses of water resources impacts, partial equilibrium approaches are the most appropriate. Once an assessment method has been selected and tested and the necessary data have been collected, the key inputs and assumptions need to be formulated. Before applying a method it is necessary to develop climatic and socio-economic baseline scenarios, climate change scenarios, and assumptions about the potential for autonomous adaptation.

CLIMATE BASELINE CONDITIONS

The climate baseline for the natural system and biophysical impacts needs to be developed with respect to temperature, precipitation, relative humidity, sunshine hours, wind speed, solar radiation and albedo. Ideally these data are daily, with maximum, minimum, and average temperatures. Monthly is the maximum time scale that is useable. The data should be a time-series with as many years of data as possible, and should be provided for as many stations as possible in each river basin being analysed and surrounding areas.

AUTONOMOUS ADJUSTMENT

The technological, economic, and policy adaptations to climate change that each user may analyse will differ greatly, depending on the hydroclimatic zone, the level of economic development, and the relative sensitivity of the water resources system to potential climate change. An impact assessment should examine potential impacts assuming no autonomous adjustment, but also should examine impacts under one or more scenarios about the level of autonomous adjustments that would occur. River basin simulation models can be used to assess autonomous adaptations as well as planned adaptations. For example, operational adaptations such as changed allocation priorities and pricing structures can be evaluated.

ASSESSMENT OF AUTONOMOUS AND PLANNED ADAPTATION

River basin simulation models can be used to assess adaptation. Structural adaptations such as new reservoirs, canals linings, and groundwater extraction can be analysed with the simulation model. In addition, operational adaptation, changed allocation priorities, and pricing structures can be evaluated. Supply adaptation, which can take three forms: modification of existing physical infrastructure; -construction of new infrastructure; and alternative management of the existing water supply systems. Demand adaptation, which can take three forms: conservation and improved efficiency; technological change and market/price-driven transfers to other activities.

WATER SUPPLY ADAPTATIONS

Since one of the major impacts of climate change is changes in the temporal and spatial distribution of precipitation and temperature, the resulting river flow or hydrologic resources may be shifted in time and space. A change in the spatial and temporal distribution of river flow could greatly affect the efficiency of the existing water supply infrastructure.

MODIFICATION OF EXISTING PHYSICAL INFRASTRUCTURE

In many countries, extensive capital investment in water supply infrastructure has been made. However, with climate change impacts, the systems may not perform as designed. Adaptation to climate change may be achieved by modifying this existing investment. In some river basins, no suitable projects exist for new development, and thus adaptation utilising existing investment is most economical. Possible adaptations to address decreased flows as a result of climate change include: changing location or height of water intakes; installing canal linings; using closed conduits instead of open channels; integrating separate reservoirs into a single system; and using artificial recharge to reduce evaporation.

Possible adaptations to address increased flows as a result of climate change include: raising dam height; adding more turbines; increasing canal size; and removing sediment from reservoirs for more storage.

Construction of New Infrastructure:-

In river basins where full development has not been realised, new projects could be built to adapt to the changed runoff and water demand conditions. These projects could include the following: reservoirs; hydroplants; delivery systems; well fields and inter-basin water transfers.

Alternative Management of the Existing Water Supply Systems:-

In some river basins, the nature of the climate change or physical, environmental, or institutional constraints do not warrant or allow new infrastructure projects. Thus, the adaptations to be considered would involve changes to the management of the existing system. Possible adaptations include the following: change operating rules; use conjunctive surface/groundwater supply; change the priority of release; physically integrate reservoir operation system and co-ordinate supply/demand.

Water Demand Adaptations:-

Water demand adaptation can be achieved through conservation and improved efficiency, technological change, or transfers to other activities.

CONCLUSION

It could be seen clearly from the above discussion that the impact of climate change on water resources can be studied through several methods and techniques. The application of each method depends upon appropriate data and information relating to temperature, rainfall, humidity, wind velocity and other climate data. The research on impact of climate change on water resources could be promoted through the following ways.

1. The government should encourage the research on impact of climate change on water resources through provision of research grants and other finance assistance.
2. Effort should be made to disseminate the research findings on the impact of climate change on water resources through government programs
3. The government should allocate more funds for research on impact of climate change on water resources.
4. There is a need to establish research center towards promotion of research on impact of climate change on water resources.
5. The researchers are motivated to conduct a large number of research on impact of climate change on water resources and also publishing its results.

REFERENCES

1. *Campos, M., A. Sanchez, and D. Espinoza. 1995. Adaptation of hydropower generation in Costa Rica and Panama to climate change. In Adapting to Climate Change: An International Perspective. Springer-Verlag, New York, pp. 232-242.*
2. *Dooge, J.C.I. 1992. Hydrologic models and climate change. Journal of Geophysical Research 97(D3), 2677-2688.*
3. *Turc, P. 1954. Water balance of soils: Relationship between precipitation, evapotranspiration, and runoff (in French). Annales Agronomique 5, 49-595 and 6, 5- 131.*
4. *Yates, D.N. 1996. WatBal: An integrated water balance model. International Journal of Water Resources Development 12(2), 121-139.*
5. *Yates, D.N., K. Strzepek, and O. Bowling. 1997. Comparison of hydrologic models Unpublished manuscript. University of Colorado, Boulder, USA.*
6. *Todini, E. 1988. Rainfall-runoff modeling: Past, present, and future. Journal of Hydrology 100, 341-352.*
7. *Kaczmarek, Z. 1991. Sensitivity of Water Balance to Climate Change and Variability, IIASA Working Paper WP-91-047. IIASA, Laxenburg, Austria.*
8. *Shaw, E.M. 1983. Hydrology in Practice. Van Nostrand Reinhold, United Kingdom. Chow, V.T. et al. 1988. Applied Hydrology. McGraw-Hill, New York.*
9. *Rawls, W.J., D.L. Brakensiek, and S.D. Logsdon. 1993. Predicting saturated hydraulic conductivity utilizing fractal principles. Soil Science Society of America Journal 57, 1193-1197.*
10. *Strzepek, K. 1994. Use of WEAP for climate change analysis. Working paper. University of Colorado, Boulder, USA.*
11. *Chapra, S. 1996. Surface Water Quality Modelling. McGraw-Hill, New York.*
12. *Kindler, J., and C. Russell (eds). 1984. Modeling Water Demand. Academic Press, New York.*
13. *Falkenmark, M. 1977. Reduced water demand — Results of the Swedish anti-pollution program, Ambio 6, 2.*
14. *Vaux, H.J. and R.E. Howitt. 1984. Managing water scarcity: An evaluation of interregional transfers. Water Resources Research 20, 785-792.*
15. *Hurd, B.H., J.M. Callaway, J.B. Smith, and P. Kirshen. 1998. Economic effects of climate change on U.S. water resources. In The Economic Impacts of Climate Change on the*
16. *U.S. Economy, R. Mendelsohn and J.E. Neumann (eds). Cambridge University Press, Cambridge, United Kingdom.*