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A Review on Inventory Modeling For Water Resource Management

Nandita dutta , PhD Scholar ,Assam University, Silchar and Prof Karabi Dutta Choudhury
Department of Mathematics, Assam university, Silchar.

Abstract: *Inventory modeling is a very important part of Operations Research, which may be used in day to day in real life. To make it applicable in real life situation, researchers are engaged in developing the newer models on different parameters under various circumstances. In water resources management, inventories play an important role. An attempt has been made in this paper to review the inventory models for decision making in water control management in different parameters such as communication cost, unit cost, reservoir protection costs etc.*

Keywords: *Inventory Models, Reservoir, Water resources management, Wetland, sonbeel.*

I. Introduction

Inventory modeling is one of the most developed fields of Operations Research. Inventories area essentially required everywhere. From production to distribution and then to final customer, the role of inventory is incomparable. Generally inventory planning and control is concerned with the acquisition of all materials necessary for supporting various business operations .Models are increasingly being relied upon to inform and support natural resource management. Water is one of the most valuable resources being an essential life-sustaining element which cannot be substituted. Water resources management presents a variety of challenges, and growing world population make certain demands on the existing water resources across the world. Water resources are among the most important factors which could be affected by climate changes and recent global warning. The water resources management approach helps to manage and develop water resources in a sustainable and balanced way, taking account of social, economic and environmental interests. The goal of sustainable water management is to promote water use in such a way that society's needs are both met to the extent possible now and in the future. This involves protecting and conserving water resources that will be needed for future generations. They also serve a variety of purposes such as water supply, flood protection, hydropower production, navigation, recreation, waste reduction and transport.

The global warming, rainfall and wind pressure are critical challenges to water control management models built on traditional premises, hypotheses and theorems. It needs a new framework, strategic approach, elaborate hypotheses and comprehensive models to ensure sustainability in the management of both water resources and related disasters. Reservoir storage is necessary to use the extremely variable water resources of a river basin for beneficial purposes such as municipal and industrial water supply, irrigation, hydro-power generation, navigation and flood protection for downstream areas. Dams and appurtenant structures are required to control highly fluctuating river flows to reduce flooding and develop reliable water supplies public recreation, water quality, erosion, sedimentation, protection and enhancement of fish, wildlife, and other environmental resources are important consideration in managing reservoir/river system .Management of the water and related land and environment at resources of a river basin integrates natural and man- made systems. Reservoirs are essential for regulating flow fluctuations to develop dependable water supplies and mitigate floods. Flow conditions vary from a dry stream to major floods. Both seasonal within year variations and multiple- year droughts are important in reservoir /river system operations. Spatial variations in geography, economic development, and climate are also key considerations in water resources development and management.

A reservoir management system that is capable of determining optimal operating rules both for normal as well as for flood event based operation while at the same time attempting to achieve as ecologically oriented reservoir operation. Reservoir operators need to know how much water to release and when. The standard policy for reservoir operation can be stated as follows**.**

First if there is not enough water to meet the target demand, release all water from active storage. Second, if there is more than enough water, release enough to meet the target demand, unless there is more water than can be stored, in which case the excess is also released.

Some objectives of reservoir management system are
1. Maximizing the amount of water available for conservation purposes and maximizing available for storing future flood waters to reduce downstream damages.
2. Minimizing agriculture water shortages.
3. Minimizing the maximum reservoir water level.
4. Minimizing the discrepancy between the optimized water level and target water level at the end of optimization.

A management is required for distribution of water in sufficient quantities at sufficient head when and where needed .Inventory control policy is required to fulfill this Job in optimum way. The United State Army Corps of Engineers (USACE) is the primary agency responsible for flood control for major reservoir system. Reservoir operating policies typically involve dividing the total storage capacity into three zones.

The **BOTTOM ZONE**, called inactive pool, is located beneath the low level outlet so that no release is possible .Water releases normally are not made from the inactive pool, except through the natural process of evaporation and seepage. The top of inactive pool elevation may be fixed by the invert of the lowest outlet or in the case of hydro-electric power, by conditions of operating efficiency for the turbines. The inactive pool is sometimes called dead storage .It may provides a portion of the sediment reservoir, head for recreation and fish habitat.

The **TOP ZONE**, called flood control storage is empty and used only during periods of high level flows so that releases will not exceed downstream channel capacity. Release decisions depend upon whether or not the flood control storage capacity is exceeded. Flood control pool operations are based on minimizing the risk and consequences of making releases that contribute to downstream flooding, subject to the constraint of assuring that a pre-specified maximum design water surface is never exceeded. The Corps of Engineers is responsible for operating a majority of the major flood control reservoir systems in the nation.

When the top zone is exceed, the **MIDDLE ZONE**, called conservation storage is utilized to satisfy day to day demands .Conservation storage purposes such as municipal and industrial water supply, irrigation, navigation, hydro electric power and in stream flow maintains, involve storing water during periods of high stream flow and/or low demand for later use as needed. Water must be stored through many wet years to be available during drought conditions.

Through the inventory management, optimization` can assume how much water is to be reserve and when to release. Water resources management presents a variety of challenges, and growing world population make certain demands on the existing water resources across the world. Effective management of water resources is becoming one of the most important challenges of our era to resolve, for maintaining and improving the living standards of developing countries .One area of great need is the optimal management and operation of existing reservoirs and water allocation which are critical issues in sustainable water resources management due to increasing water demand by various sectors.

Water demands change from year to year and month to month. In recent years, significant climate changes have been observed in many parts of the world, including more severe floods, greater precipitation, and even unusual droughts in many areas. These changes have considerably influenced the water demands in many parts of the arid and semi-arid lands like India, Bangladesh etc.

As per record available, the average rainfall is 3180mm and average rainy days 146 per annum at the southern part of Assam i.e. in the Barak Valley Region. Still the scarcity of pure water in most part of the region is an alarming situation. But the biggest fresh water Lake Sonbeel is situated at Northern half of Karimganj district. By applying the inventory modeling and optimization technique may be developed to make Sonbeel a river basin where a particular level of water may be maintained to meet the demand of water of the locality throughout the year. At the same time, the attempt is to be made to maintain the ecological balance of the area.

II. Literature Review

Daniel. P. Loucks et.al (2005) written the book, Water Resource Systems Planning and Analysis .This book introduces the science and art of modeling in support of water resources planning and management. It also discusses how modeling activities in water resources development, planning and management projects should be managed. This book describes the kinds of problems of water managers can face and the types of models and methods one can use to evaluate alternative development plans and management policies. It provides many dimensions of water resources management and presents practical approaches for analyzing problems and identifying ways of developing and managing water resources systems in a changing and uncertain world. A variety of optimization and simulation models have been developed to help water planners and managers in identifying and evaluating plans. People who are involved in water resources planning and management get benefited from this book.

With growing scarcity and increasing competition for water across sectors, the need for efficient, equitable, and sustainable water allocation policies has increased in importance in water resources management. Therefore an integrated hydro-economic model has been developed.

Luwesi, et. al. (1999) used hybrid inventory models under above normal (ANOR), normal (NOR), and below normal (BNOR) economic conjunctures. These models combine include both internal and external costs incurred in the management of inventories in order to simulate efficient levels of money and physical assets use in production under fluctuating economic conjunctures. Internal costs include both the cost of transaction and opportunity cost, while external costs include the cost of saving under ANOR, and the shortage cost under BNOR. Finally, the analytical process assesses the variations of incomes vis-à-vis costs under different hypotheses of the management efficiency (EOQ, LAC and MES) to design strategic guidelines.

Luwesi et.al (2010) discussed Hydro-economic inventory in a changing environment: It assesses the efficiency of farming water demand under fluctuating rainfall regimes in semi-arid lands of South-East Kenya. South-East Kenya is particularly facing increased risk of crop failure due to increased farming water costs under rainfall variability This study used hybrid inventory models that integrates spatially distributed variables of plant water use with mathematical description of water availability and farmers' water demand. It assesses hydro- geomorphologic impacts affecting efficient use of farming water in Muooni Catchment. It may foster efficient water use in the course of climate change.

Luwesi, et. al. (2011) discussed hydro-geomorphologic, social and economic risks related to irrational use of farming water and land of Kenya. This study offered a novel approach for achieving sustainability in a watershed and mitigating recurrent water shortages in farming.It utilized an "hydro economic" procedure to assess the risks related to farming water and land use, and served as a basis for mitigation planning, implementation, monitoring and evaluation of water disasters in agriculture in the catchment area. This hydro-economic risk assessment and management would help the government to foster the implementation of "Integrated watershed management" (IWM) in different catchments of the country.

Joy Apiyo Obando, et. al. (2013) discussed Hydro-Economic Inventory Models for Planning and Evaluation of Farming Water Efficiency in a Semi-Arid Watershed of Kenya. Water stress and its unsustainable use are threatening farming efficiency in most "Arid and semi-arid lands" (ASALs) of Kenya. It focuses on an incremental analysis of crop inventory models. Results of this study show that significant increase of water shortage costs under below normal rainfall regime (BNOR) undermines agricultural efficiency. Almost all farming units need to define a "Minimum efficient scale" (MES) of their farming water demand to optimize their crop water requirements under recurrent risk of drought. Farmers also need appropriate farming technologies and rational water policies to foster their economic efficiency.

Shisanya, C.A. et. al. (2013) discussed Inventory Models for Evaluating Water and Food Security: Approaches and Lessons from Smallholder Farms of Muooni Catchment, Machakos District, Kenya This paper try to explain food shortage in a water scarce Muooni catchment using operational research inventory model. Results indicate that Muooni dam siltation and subsequent water stress threatens the economic viability of smallholder farms in the catchment. They increase significantly the costs of water saving and shortage costs in farming, threatening agriculture economic viability and food security .

Subramanian (2001) indicates that "Water problems in developed countries have been solved only by reservoir storage at different stages of the river flow". So, if water shortage problems are solved quickly in the ASALs of India, it is simply because of adaptation of traditional water storage systems to drought, mainly using deep ponds, storage wells and underground tanks. They advise the use of efficient methods and empirical techniques of water use in farming. It suggests that farmers mainly optimize their farming water costs to ensure high yields and income.They suggested Inventory models to be major tools for assessing efficiency, effectively forecasting and allocating resources even under uncertainty.

Jonathan Chenoweth et. al. (2008) discussed Freshwater Use Impacts in LCA Inventory Modeling and Characterization Factors for the Main Impact Pathways. Fresh water is a basic resource for humans. This paper show how this fresh water resource use can be deal with in LCA. It is crucial for Life Cycle Inventory (LCI) to distinguish between evaporative and non-evaporative uses of freshwater. This study provides guidance to quantify both types of uses for the main processes commonly assessed with LCA. The main quantifiable impact pathways linking freshwater use to the available supply are identified, leading to definition of the flows requiring quantification in the LCI. Result shows that the LCI needs to distinguish between and quantify evaporative and non-evaporative uses of blue' and 'green water, along with land use changes leading to changes in the availability of fresh water.

Rick L. Wilson. et. al (1997) discussed the design and development of the Water Resource Management System (WREMS). Many management science models proposed for optimizing various operational aspects of municipal water systems. The practical experience indicates that water managers view such modeling attempts with skepticism The main distinction of the WREMS system is that the optimization model used to offer operational guidance is imbedded within an inventory data management informtion system and it try to grow the interest of the city water managers in trusting and, ultimately, using the system. It designed to assist in making daily decisions such as which wells to produce and how to manage water levels in reservoirs.

Ralph A. Wurbs (**2005)** worked in the water resources development program regarding various aspects of reservoir /river system management. Reservoirs play a fundamental role in water resources management throughout the world. Reservoir/river system analysis models are used for various purposes in a variety of setting. Models are used in planning studies to aid in the formulation and evaluation of alternative plans for responding to water related problems and needs. This paper provides a general overview of the inventory of reservoirs in the United States, the institutional framework for river basin development and management, reservoir operating practices, and computer modeling applications. Reevaluation studies may also be made in response to a particular perceived problem or need. Studies may be motivated by drought conditions, a major flood event, water quality problems, or environmental losses such as fish kill.

Shisanya (2005) observed that farmers living in the rural areas of Kaka mega in western Kenya, and more precisely 58% of them, are facing serious challenges related to potable water accessibility during drought.These factors impact directly on the maintenance of the catchment environment through increased socio-economic externalities leading to deforestation, soil erosion, water pollution and others. It arises from this analytical description that farming water saving strategies, whether within a modern or traditional context encompass two main sets of mechanisms: "Blue Water Supply" (BWS) projects on one end, and "Green Water Saving" (GWS) schemes on the other.

Rose A. Akombo et al.(2014) discussed Green Water Credits for Sustainable Agriculture and Forestry in Arid and Semi-Arid This paper focuses on Green Water Credits (GWCs) and Payments for Watershed Services (PWS) schemes. It is worth looking at different water saving mechanisms used by Kenyan farmers in ASATs. Green Water Credits (GWC) schemes have been propounded to be bio-physically needed, technologically possible, politically and socially acceptable, and economically feasible for ensuring adaptation to and mitigation of climate related water disasters. Results of this study show that Investments in GWCs are needed to increase the volume of accessible blue water in streams and lakes as well as groundwater, in order to foster a green revolution in the ASATs. This will mitigate impacts related to water disasters and crop failures, as well as alleviate farmers' poverty. However, farmers little income and lack of benefits is a serious impediment to the economic efficiency and successful management of GWCs.

B.P. Hooper (2005) is written in his hand book primarily for basin managers and government officials who need to take decisions related to water management. They have to put in place management systems that will mitigate the impacts of natural hazards, supply water for productive purposes (agriculture, industry, energy, transport, tourism, fishing, etc and supply water for social purposes (health and domestic services) and protect the environment. They must, therefore, manage conflicts on water resource issues between many different users. The handbook is also aimed at non-governmental actors who are involved in basin activities . It provides practical guidance for improving the governance of freshwater resources, in particular through effective application of the integrated water resources management (IWRM) approach in lake and river basins, and aquifers.

Jaetzold *et al.* (2007) observe that Kenya agricultural sector is highly vulnerable. It depends on marginally degraded lands, whereas water scarcity and land infertility undermine resources productivity. Arid and Semi-Arid Lands (ASALs) in Kenya represent about 85% of the whole country area. Therefore, one way of assuring food security and poverty alleviation is to plan the long-term availability of water and land resources through programmers dealing with efficient agricultural production. Efficient farming systems are based on the inventory of available resources and the evaluation of their potential productivity in connection with their physical and operational costs. This helps in determining the economic efficiency of watershed resources use in agriculture. Soil fertility improvement and land management are suggested as basic tools for improving crop production efficiency.

M.Q.Suo,et al (2011) discussed an inventory theory- based interval parameter-two–stage stochastic programming (IB-ITSP) model and apply it to water resources management systems. This method can provide effective measures for solving water shortage problems and afford useful information for decision makes under uncertainty. The proposed method not only can address multiple uncertainties but also can generate reasonable transferring batch and period associated with different flow levels and transferring costs. They can be used for generating decisions alternatives and thus help water resources managers to identify desired policies.

Previously ,a great number of researchers made efforts to address uncertainties in water resources management systems through stochastic programming(Loucks et al.1981,Trezos and Yeh 1987 ,Kelman et al. 1990, Ruszczynsk,1993,Huang1998, Haurie and Moresino2000, Seifi and Hipel2001,Maqsood et.al.2005, Li et al.2006,2008b,2009,Zhang et al.2009).Among them ,Two-stage stochastic programming was an effective technique for problems where an analysis of policy scenarios as desired and the related data are mostly uncertain.

The inventory theory-based interval parameter-two–stage stochastic programming (IB-ITSP) model did not consider the dynamic variations of system conditions, particularly for sequential influences of different flow levels among multiple stages. In addition, multiple uncertainties existed in water resources management systems, such as the continuously changed water availabilities, various targeted water demand associated with timely policy scenarios, and fluctuant water benefit as well as related transferring cost. The conventional inexact optimization methods had difficulties in tackling such complexities.

Therefore, as an extension of the previous efforts, **M.Q.Suo (2013)** developed an inventory-theory-based inexact multistage stochastic programming model (IB-IMSP) for supporting water resources management planning. The IB-IMSP is an integrated method of inventory theory, inexact optimization, and multistage stochastic programming. The IB-IMSP not only handle system uncertainties but also reflect dynamic features of system conditions under different flow levels within a multistage context .Its provide reasonable transferring schemes (the transferring amount, batch, and the corresponding transferring period) associated with various flow scenarios would be provided for decision makers for solving water shortage problem. The applicability of the proposed IB-IMSP is demonstrated by a case study of planning water resources management. The results obtained can help the managers gain insight into the water resources management with maximizing economic objectives and satisfying targeted water demands from users. Although this sudy is the first attempt for planning water resources management by the proposal of an IB-IMSP method.

Y. Xu, G.H. Huang & L.G. Shao (2014) explained agricultural farming planning and water resources management under fuzzy uncertainty. This paper presents, a rank-based fuzzy optimization (RBFO) approach was provided for supporting agricultural farming planning under complex uncertainties. . A farm planning case with water resources management consideration was used to demonstrate the applicability of RBFO. The results of this study show that rank-based fuzzy optimization (RBFO) systems analysis approach could help decision makers to gain a deep insight into the complex interrelationships among agricultural economic development, and water resources conservation in a farm planning system .It also seek cost-effective production patterns with favorable deliberation of various factors.

Y. P. Li & G. H. Huang (2009) discussed an inexact two-stage integer program with joint-probabilistic constraint (ITIP-JPC) is developed for supporting water resources management under uncertainty. The (ITIP-JPC) is applied to a case study of water resources allocation within a multi-stream, multi-reservoir and multi-user context, where joint probabilities exist in both water availabilities and storage capacities. , It also used for analyzing various policy scenarios that are associated with different levels of economic consequences when the pre-regulated targets are violated. . The results show that reasonable solutions have been generated for both binary and continuous variables. They can help generate desired policies for water allocation and flood diversion with a maximized economic benefit and a minimized system-disruption risk.

III. Discussion

Sonbeel is the largest Oxbow lake (Wetland) of Asia. Located in Karimganj District of the Southern Assam North East India. Sonbeel is connected with two major rivers of the valley namely Singhla and kochua. .Son beel is a natural basin situated between Singla and Kachua River. Sonbeel facing of water related problem .As there is no proper water management system for Sonbeel, during rainy season surrounding population suffers from flood and in winter the beel dries up almost 95%causing water scarcity in the area. Because of lack of water management system huge amount of rain water cannot be harvested and wasted. If presently water control measures are not taken sonbeel will face the economic crisis If the government can control the rivers the Singla and its tributaries creates dam or reservoir, small power plant project then it benefited the local people of sonbeel economically. The agricultural land also will save from water scarcity. The main resource of the son beel is water and at the same time the main problem of the same is also its uncontrolled water. The inventory model can be developed for storage of optimum of water level in the son-beel and may be used as the reservoir to retain optimum water level and spread area throughout the year. Present study will be based on the water level management of Sonbeel for optimum use of water resources such as agriculture, fish cultivation, tourism etc by using the inventory modeling.

IV. Conclusion

Optimal utilization of irrigation, hydro electric power generation, municipal and industrial water supply and navigation water management system plays a vital role to meet all the demands. According to the inventory policy it is adopted to meet the demand and to maintain equilibrium in the water level .Through the inventory management optimization technique, water management organization can assume how much water is to reserve and when to release. In this study, the inventory model can be used for optimal utilization of the available water resources of sonbeel of any reservoir system to obtain maximum benefits.

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