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Original Article

Blue Print for Green Revolution in South Eastern River Basin, Nigeria using Bayesian and Game Models

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Abstract - *The study aimed to develop a Blueprint for the Green Revolution in the south-eastern basin of Nigeria, using Bayesian and Game Theory models as climate variability solutions. The objectives were to use multipurpose/multi-objective capital projects to develop a blueprint for a green revolution at the river basin. The methodology uses Bayesian and Game decision theories based on the Bill of Engineering Measurement and Evaluation (BEME) data. The result shows that the optimal solution from the Bayesian Model analysis of the Maximum Expected Monetary Value (EMV*) was N68.72 billion. The optimal strategies for the Game theory were a maximum benefit of N69.02 billion, which is N0.30 billion higher than the result obtained from the Bayesian analysis. The amount of ₦12.504 billion released to the south-eastern Nigeria river basin for the period was deducted from the revenue generated from Bayesian EMV* (₦68.72 billion), and optimal strategies of Game (₦69.022 billion), then ₦56.22 billion and ₦56.52 billion respectively emerged which were the profit margins for the investment. The work concluded that since many uncertainties in climate change projections impact the ecosystem, optimal strategies should incorporate delivering benefits irrespective of climate conditions. It was recommended that status assessment, understanding the assumption made, long term consistent monitoring of data, long term effectiveness and cost efficiency, certainty in climate priority and posteriority predictions and logical cost sharing would assist in the use of green and clean energy sources for project development at the river basin. This would generate revenue and enhance social wellbeing for communities of the region. The allocation of money released for these ten development projects resulted in optimal benefits. The Bayesian and Game optimization offer an alternative solution for developing the blueprint for a green revolution at the river basin.*

Keywords - *Bayesian theory, Blueprint, Game theory, Green revolution, Optimal benefits.*

1. Introduction

Human-related activities like greenhouse gas (GHG) emissions, burning of fossil fuel, and construction-related activities have led to variability in rainfall, temperature, and other climatic conditions. The organizational inadequacies to manage uncertainties, projections and scenarios in climate change, financial constraints, and lack of logical cost sharing in multipurpose projects resulted in food insecurity, deforestation, erosion-induced gullies, unbalancing of the ecosystem, pollution of air, land and water, human suffering loss of lives and properties etc. These are the daunting challenges that affect multipurpose/multi-objective project development at the river basin. Eme and Ohaji (2019). Climate variability is also a significant factor in managing river basins, which would impact a wide range of implementation strategies. Changes in water temperature, river flow and recharge of groundwater, water availability, intensity and frequency of extreme events such as floods and droughts, rise in sea level and saltwater intrusion, pollution, land changes and water quality are the most relevant physical and chemical factors. Potential impacts may include loss of vulnerable species in potential areas, invasion, water supply, hydro-infrastructure, and land use on freshwater ecosystems. Adequate climate change adaptation would have a global potential contribution to multiple sustainability challenges essential for improved and integrated river basin planning and management. Water resources in many rivers are fully committed to various human uses. Portable water quality in degraded river-dependent ecosystems is threatened, and the expanding demand for water sometimes leads to competition and strife. The water management challenges to agriculture were to maximize agricultural production with less water from river basins that are already stressed. The judicious assessment of new water infrastructures in open water basins is necessary to ascertain the possibility of better operations for the benefit of the communities. All land on earth's surface is part of one river basin or the other, and most of the land is divisible into river basins by the nature of the environment. Although the effort to Control Rivers was initiated many years ago, the concept of river basins as units for planning, developing and managing water emerged in the late 19th and early 20th centuries. The control of water estimation of extreme events and management of climate variability posed many problems unanticipated by engineers in Nigeria. There is a need for proper coordination of the use of river basins and the logical stem to use water resource development as an integrating social, economic and environmental condition to reduce human activities and intervention in the water cycle, which placed many river basins under stress (Data and Harikrisha, 2005). River systems linking the downstream are complex with multiple associated stresses, such as the effects of changes in water and sediment flows, canalization, wetland reclamation, pollution (including legacy pollution), and water abstraction. The impact of these stressors may be greater in the short term when compared to the current effects of climate change and sea level rise on some river systems. When combined with climate change, these stresses often introduce different dynamics, resulting in a strong decline in the functioning of the natural ecosystem and quality of river systems, which complicates existing stresses. There is an interaction in river systems with the river, the catchment area and the outside world (CIS, 2009). In order to achieve a sustainable climate change solution in River Basin Development Planning and Management, there should be a growing interest in institutional processes that bring together fragmented water users into an integrated planning, allocation and management framework essential for adaptation to climate change with a global potential contribution to multiple sustainability challenges (Cosgroove and Loucks, 2015).

The multi-disciplinary nature of multipurpose/multi-objective river basin development projects, as well as planning and management, may involve a lot of complex situations. Identifying the best way a river basin and its tributaries may be used to meet competing demands while maintaining river health is an essential process for their planning and management (Barrow, 1998). Some challenges include allocating scarce water resources between different users and purposes, choosing between environmental objectives, competing human needs, and competing food risk management requirements (Molle, 2006). The increasing complexity of many river basins, occasioned by increasing development and population pressure, has resulted in many serious crises related to floods, degradation of water quality, acute water shortage and degradation of ecological health. The various approaches to river basin planning ultimately play significant roles in adapting to the local circumstances. The consideration of economic efficiency, federal economic redistribution, regional economic redistribution, state economic redistribution, local economic redistribution, social wellbeing, environmental quality improvement, youth empowerment, gender equality and security are becoming more relevant due to some political, ecological and health concerns of the people. Ezenweani (2017) identified that the inability of the management of the river basin to control the whole basin and the lack of baseline data with inadequate monitoring are some of the problems that hinder river basin development planning and management. Klare (2001) also said that politics determine who will be employed, what is on the agenda and how river basin development planning and management proceeds affect them. The required decisions will need to be made by concerned stakeholders in the government and river basin development authority for adequate benefits to be derived from the resource development and utilization (Eme, 2015). Climate variability uncertainties, inadequate use of projections and scenarios, climate change indicators with long term consistent monitoring data, deforestation, food insecurity and freshwater quality pollution at various locations are hindrances to achieving effective operations at the river basin. The Bayesian and Game theories model optimization techniques were used to develop a blueprint for the green revolution to mitigate climate variability at the river basin.

2. Aims and Objectives

The aim was to use Bayesian and Game theories model optimization to develop a blueprint for a green revolution in Nigeria's south eastern river basin. The objective was to determine optimal benefits under the multipurpose/multi-objective projects using these models to develop a blueprint for a green revolution at the river basin.

3. Review of Bayesian and Game Theories Literature

The Bayesian theory is an optimization technique in dynamic programming to help prioritize multipurpose projects for optimal benefits, while game theory optimization, as a dynamic programming technique, would be used to optimize resource allocation to various multipurpose projects for optimal benefits. The terminologies for these optimization techniques are stated below in sections 3.1 and 3.2 based on Sharma (2008).

3.1. Bayesian Theory Analysis

This concerns computing posterior probability from prior probabilities using Bayes' theorem. A prior probability distribution is an initial probability statement to evaluate the expected payoff. The one revised in the light of new information is called a posterior probability distribution. What is a posterior to one sequence of state of nature becomes the prior to others, which is yet to happen. Further analysis of problems using these probabilities with respect to new expected payoffs with additional information is called prior-posterior analysis. The general terms of Bayes' theorem can be stated as follows:- Let A_1, A_2, … A_n be mutually exclusive and collectively exhaustive outcomes. Their probabilities $P(A_1)$, $P(A_2)$, … $P(A_n)$ are known when there is an experimental outcome, B for which the conditional probabilities $P(B/A_1)$, $P(B/A_2)$, … $P(B/A_n)$ are also known given the information that outcome B has occurred, the revised conditional probabilities of outcomes A_i, i.e. $P(A_i/B)$, $i = 1, 2, …, n$ are determined by using the following conditional probability relationship:

$$P(A_i/B) = \frac{P(A_i \text{ and } B)}{P(B)} = \frac{P(A_i \cap B)}{P(B)} \quad (1)$$

Where $P(B) = P(A_1 \cap B) + P(A_2 \cap B) + \cdots + P(A_i \cap B)$. Since each joint probability can be expressed as the product of a known marginal (prior) and conditional probability, $P(A_i \cap B) = P(A_i) \times P(B/A_i)$

$$\text{Thus } P(A_i/B) = \frac{P(A_i)P(B/A_i)}{P(A_1)P(B/A_1) + P(A_2)P(B/A_2) + \cdots_{-} + P(A_n)P(B/A_n)}$$

The Bayesian Analysis involves the computation of Expected Monetary Value (EMV), Expected Opportunity Loss (EOL), Expected Value of Perfect Information (EVPI), Expected Profit with Perfect Information (EPPI) and Expected Value of Sample Information (EVSI).

3.1.1. Expected Monetary Value (EMV)

The Expected Monetary Value (EMV) or Expected Utility is the most widely used criterion for evaluating various courses of action (alternatives) under risk. The Expected Monetary Value (EMV) for a given course of action is the weighted sum of possible payoffs for each alternative.

It is obtained by adding the payoffs for each course of action multiplied by the probabilities associated with each state of nature. The expected (or mean) value is the long-run average value that would result if the decision were repeated many times. Mathematically, EMV is stated as follows:

$$\text{EMV (Course of action}, S_i) = \sum_{i-1}^{m} P_{ij}P_i \quad (2)$$

Where m = number of possible states of nature
P_i = probability of occurrence of a state of nature N_i
P_{ij} = Payoff associated with state of nature, V_i and course of action, S_j.

Calculating EMV involves the following steps:

1. Construct a payoff matrix using all possible courses of action and states of nature
2. Enter the conditional payoff values associated with each possible combination of course of action and states of nature, along with the probabilities of the occurrence of each course of action.
3. Calculate the EMV for each course of action by multiplying the conditional payoffs by the associated probabilities and add these weighted values for each course of action.
4. Then, select the course of action that yields the optimal EMV*.

3.1.2. Expected Opportunity Loss (EOL)

Expected Opportunity Loss (EOL) is an alternative approach to maximizing the expected monetary value (EMV) by minimizing the expected opportunity loss (EOL). This is also called the expected value of regret. Expected Opportunity Loss means the difference between the highest profit (or payoff) for a state of nature and the actual profit obtained for the particular course of action. EOL is the payoff lost by not selecting the course of action with the highest payoff for the state of nature that occurs. Due to which EOL is at a minimum, the course of action is recommended. The Expected Opportunity Loss as an alternative decision making under risk is synonymous with the EMV criterion, so any two methods are applied to reach a decision. Mathematically,

$$\text{EOL (state of nature}, N_i) = \sum_{i=1}^{m} E_{ij}P_i \quad (3)$$

E_{ij} = opportunity loss due to state of nature, N_i and course of action, Sj.
P_i = probability of occurrence of a state of nature, N_i.

The following steps are involved in the computation of Expected Opportunity Loss (EOL):

1. Prepare a conditional profit table for each course of action, state-of-nature combination, and associated probabilities.
2. Calculate the Conditional Opportunity Loss (COL) values for each state of nature by subtracting each payoff from the maximum payoff for that outcome.
3. Calculate EOL for each course of action by multiplying the probability of each state of nature with the COL value and adding up the values.
4. Select a course of action for minimal Expected Opportunity Loss (EOL).

3.1.3. Expected Value of Perfect Information (EVPI)

For a decision maker under risk, perfect (complete and accurate) information about the occurrence of various states of nature will make him select a course of action that yields the desired payoff for whatever states of nature that occurs. EMV or EOL criterion helps the decision maker select a particular course of action that optimizes the expected payoff without additional information.

The Expected Value of Perfect Information (EVPI) is the maximum amount of money the decision maker has to pay to get this additional information about the occurrence of various states of nature before a decision is made.

Mathematically

$$\text{EVPI} = (\text{Expected Profit with Perfect Information}) - \text{Expected profit without Perfect Information}$$

$$\therefore \text{EVPI} = \sum_{i=1}^{m} P_{ij} \max(P_{ij}) - \text{EMV} \quad (4)$$

where;
P_{ij} = best payoff when action, $S_{j,}$ is taken in the presence of state of nature, N_i.
P_i = probability of the state of nature, N_i;
EMV* = maximum expected monetary value.
∴ EVPI = EPPI – EMV*.

3.1.4. Expected Profit with Perfect Information (EPPI)

Expected Profit with Perfect Information (EPPI) is determined or calculated by summing up the multiplication of prior probabilities on each state of nature by the largest values on each course of action.

3.1.5. Expected Value of Sample Information (EVSI)

Expected Value of Sample Information (EVSI) is obtained by multiplying posterior EOLs with their probabilities. This represents the money the decision maker has to pay to hire the services of a consultant.

3.1.6. Courses of Action (actions, acts or strategies)

Courses of Action (actions, acts or strategies) is the number and type of alternatives, though they may be dependent on the previous decisions made and on what has happened subsequently to those decisions under the control of the decision maker, e.g. conditioning a market survey to know the likely demand of an item.

3.1.7. States of Nature

States of Nature are the future conditions (also called consequences, events or scenarios) not under the control of the decision maker, e.g., the state of the economy (inflation), a weather condition, a political development, an act of God, etc.

The States of Nature are mutually exclusive and collectively exhaustive with respect to any decision problem.

3.1.8. Payoff

Payoff is a numerical value (outcome) resulting from each possible combination of alternatives and states of nature. The payoff values are always conditional because of unknown states of nature. The payoff is measured within a specified period (e.g., yearly), which is the decision horizon. The payoffs considered in most decisions are monetary, measured in terms of money market share or other measures.

3.2. Game Theory Model

The following definition of Game Theory was based on Sharma (2008). A game is a situation of conflict and competition in which two or more competitors (or participants) are involved in decision-making in anticipation of certain outcomes over time. In the game, competitors referred to as players may be an individual, a group of individuals, or an organization. When using the theory of games to select an optimal strategy for two or more competitors in a competitive and conflicting decision environment, it can be used in the pricing of products, various television networks, the success of a business tax strategy and the success of an advertising/marketing campaign etc. The theory of game as an area of academic study provides a series of mathematical models that may be useful in explaining interactive decision-making concepts where two or more competitors are involved under conditions of conflicts and competition. Although it is limited in scope as a practical tool, the models provide an opportunity for a competitor to evaluate not only his alternatives (courses of action) but also the evaluation of the opponent's (or competitor's) possible choices in order to win the game is also considered.

3.2.1. Number of Players

When two players (competitors) are involved, it is referred to as a two-person or n-person game for more players.

3.2.2. Zero-Sum Game

This means that the sum of gains to one player is exactly equal to the sum of losses to another player, such that the sum of gains and losses equals zero. Otherwise, it is called a non-zero-sum game.

3.2.3. Strategy

This is the list of all possible actions (moves or courses of action) the player will take for every payoff (outcome) that might arise.

3.2.4. Optimal Strategy

Optimal Strategy is the particular strategy by which a player optimizes gains or losses without knowing the competitor's strategies. If the maximum valve equals the minimal values, the game is said to have a saddle (equilibrium) point, and the corresponding strategies are called optimal strategies.

3.2.5. Value of the Game

Value of the game is the expected outcome per play when the players follow their optimal strategy.

3.2.6. Pure Strategy

This is the decision rule the player always uses to select the particular strategy (course of action). Each player knows in advance all strategies and always selects only one particular strategy regardless of the other player's strategy, whose objective is to maximize gains or minimize losses.

3.2.7. Mixed Strategy

Implies that the courses of action are selected on a particular occasion with some fixed probability. There is a probabilistic situation where the players aim to maximize expected gains or minimize expected losses by choosing pure strategies with fixed probabilities. A mixed strategy for a player with two or more possible courses of action is the set S of n non-negative real numbers (probabilities) whose sum is unity, n being the number of pure strategies of the player. If Pj ($j = 1, 2, \ldots, n$) is the probability with which the pure strategy, j, would be selected, then $S = (P_1, P_2, \ldots, P_n)$ where $P_1 + P_2 + \ldots + P_n = 1$ and $Pj \geq 0$ for all j.

Two-person zero-sum game is a game with only two players, say player A and player B, where one player's gain equals another player's loss such that the total sum is zero. *Payoffs* represent a quantitative measure of a player's satisfaction at the end of the play. *The payoff matrix represents* the payoffs in terms of gains or losses when players select their particular strategies, represented in a matrix. *The value of the game* is referred to as the expected payoff at the end of the game when each player uses his optimum strategy. The amount of payoff V at an equilibrium point. The value of the game generally satisfies the equation, maximum value (V (minimum value). *Saddle point* occurs in a game when the minimum of the column maxima and the maximum of the row minima are equal. A game may have more than one saddle point, while a game with no saddle point is solved by choosing strategies with fixed probabilities. *A fair game* is when, in a game, the lower (maximin) and upper (minimax) values are equal, and both equals zero.

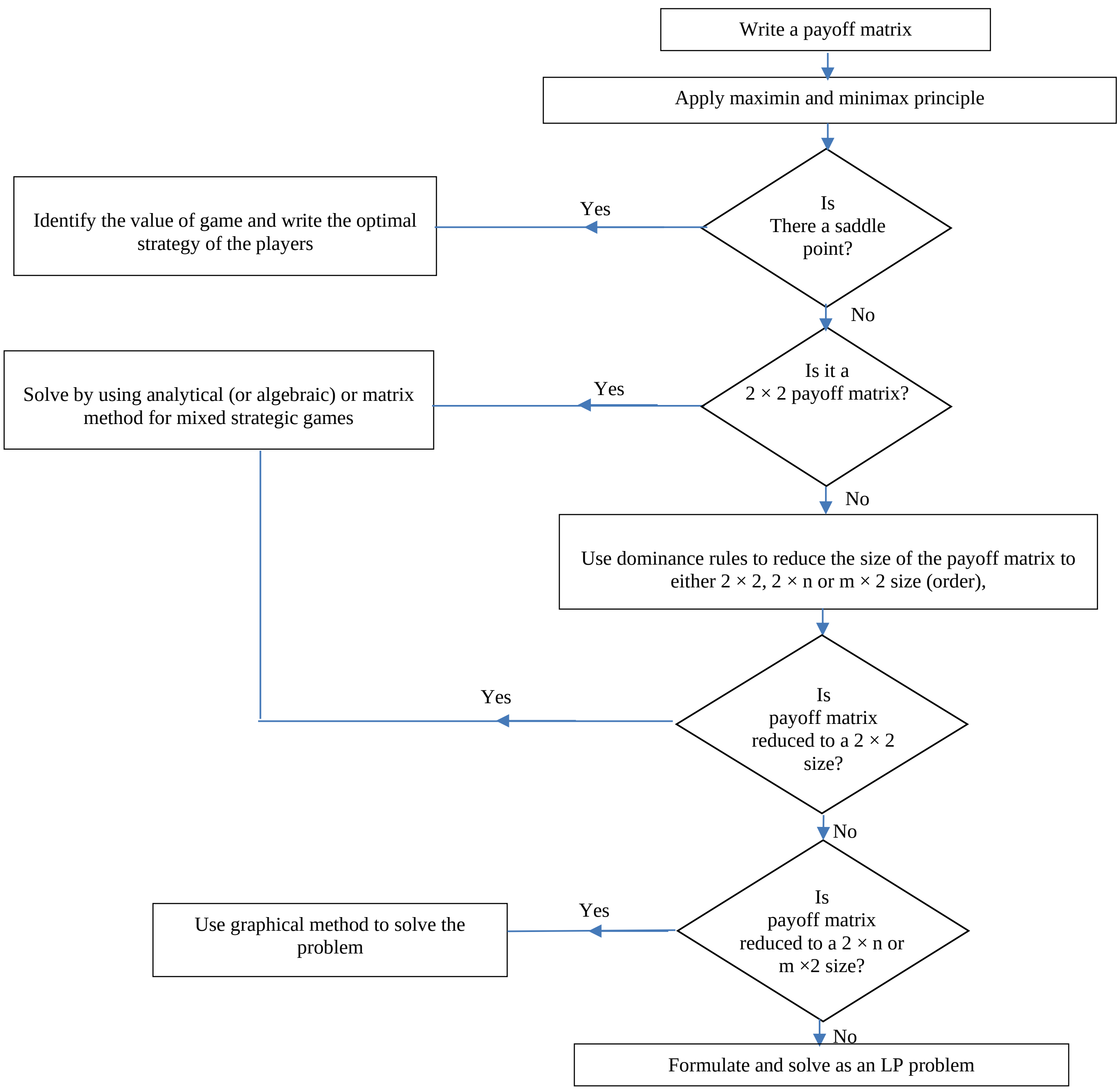

Fig. 1 Flow chart of game theory

Source: Sharma (2008)

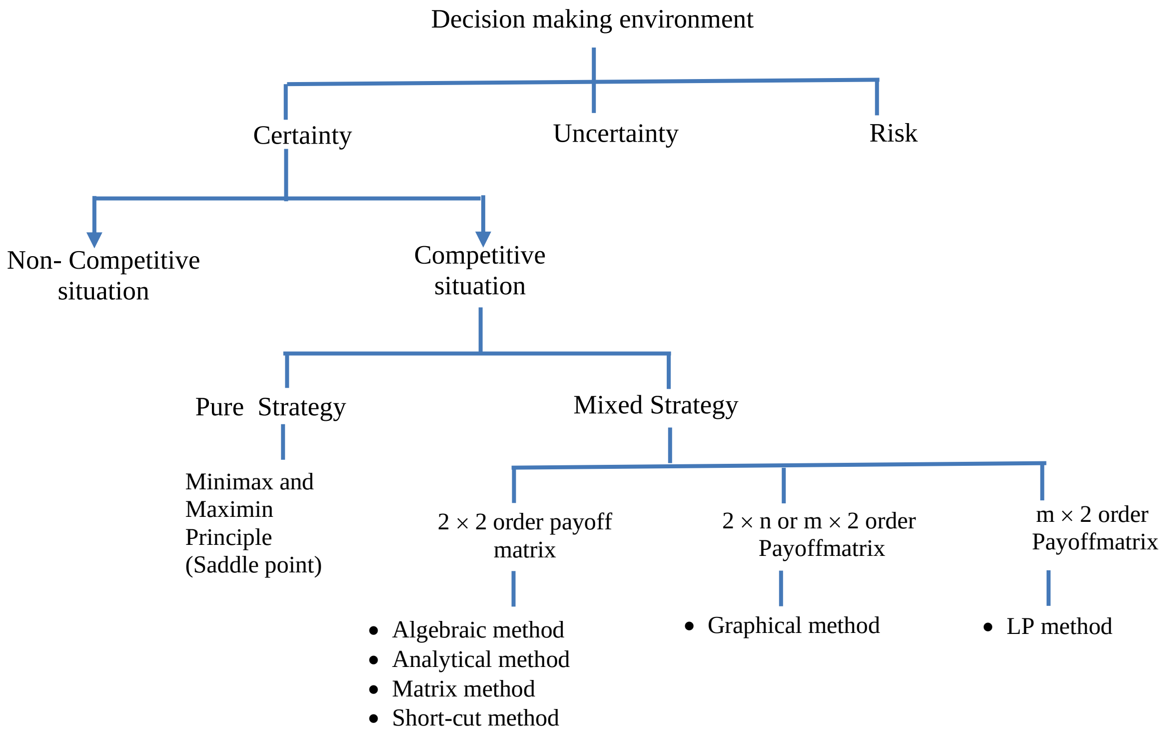

Fig. 2 Various methods to find game value under a decision-making environment of certainty

Source: Sharma (2008)

A strictly determinable game is when the lower (maximin) and upper (minimax) values of the game are equal, and both equal the value of the game.

The Maximin Principle means that player A's minimum value in each row represents the least gain (payoff) to him if he chooses his particular strategy, the row minima. He selects the strategy that is the largest among the row minimum values. The choice of player A is referred to as the *maximin principle*, and the corresponding gain is called the *maximin value of the game*.

The Minimax Principle means that for player B, who is assumed to be the loser, the maximum value in each column represents the maximum loss if he chooses his particular strategy. It is referred to as column maxima in the payoff matrix. He now selects the strategy that gives minimum loss among the column's maximum values. This choice of player B is the *minimax principle*, and the corresponding loss is the minimax value of the game.

The Rules of Dominance is the strategy used to reduce the size of the payoff matrix. These rules help delete certain rows and/or columns of the payoff matrix that are inferior (less attractive) to at least one of the remaining rows and columns (strategies) in terms of payoffs to both players. The mixed strategies game method saddle points were solved using linear programming.

Linear programming method: There is some relationship between Game theory and linear programming. Linear programming techniques can also solve two-person zero-sum games. It has the advantage of solving mixed strategy games of larger dimension payroll matrix. To illustrate the transformation of a game problem to a Linear programming problem, consider a payroll matrix of m × n size. Let a_{ij} be the element in the ith row and jth column of the game payroll matrix, and let p_i be the probabilities of m strategies (I = 1, 2, …, m) for player A. Then, the expected gains for player A for each of B's strategies will be

$$\sum_{i=1}^{n} p_i a_{ij}\,, j = 1, 2, \ldots n \tag{5}$$

The aim of player A is to select an asset of strategies with probability p_i(I = 1, 2, …, m) on any play of the game such that he can maximize his minimum expected gains. To obtain values of probability p_i, the value of the game to player A for all strategies by player B must be at least equal to V. Thus, to maximize the minimum expected gains, it is necessary that

$$\left.\begin{array}{l} a_{11}p_1 + a_{12}p_2 + \ldots . a_{m1}p_m \geq V \\ a_{12}p_1 + a_{22}p_2 + \ldots . a_{m2}p_m \geq V \\ . a_{1n}p_1 + a_{2n}p_2 + \ldots . a_{mn}p_m \geq V \\ \text{where} \quad p_1 + p_2 + \ldots + p_m = 1;\ p_i \geq 0 \text{ for all i.} \end{array}\right\} \tag{6}$$

Dividing both sides of the m inequalities and equation by V, the division is valid as long as V > 0. In case V < 0, the direction of the inequality constraints must be reserved. But if V = 0, the division would be meaningless. In this case, a constant can be added to all matrix entries, ensuring that the value of the game (V) for the revised matrix is more than zero. After the optimal solution is obtained, the game's true value is obtained by subtracting the same constant value. Let $\frac{p_i}{V} = x_i, (\geq 0)$.

Then we have

$$\left.\begin{array}{l} a_{11}\frac{p_1}{V} + a_{21}\frac{p_2}{V} + \dots . a_{m1}\frac{p_m}{V} \geq 1 \\ a_{12}\frac{p_1}{V} + a_{22}\frac{p_2}{V} + \dots . a_{m2}\frac{p_m}{V} \geq 1 \\ a_{1n}\frac{p_1}{V} + a_{2n}\frac{p_2}{V} + \dots . a_{mn}\frac{p_m}{V} \geq 1 \end{array}\right\} \quad (7)$$

where $\frac{p_1}{V} + \frac{p_2}{V} + \dots + \frac{p_m}{V} = 1.$

Since the objective of player A is to maximize the value of the game, V which is equivalent to minimizing $\frac{1}{V}$, the resulting linear programming problem can be stated as

$$Minimize\ Z_p \left(= \frac{1}{V}\right) = x_1 + x_2 + \dots + x_n$$

Subject to the constraints:

$$\left.\begin{array}{l} a_{11}x_1 + a_{12}x_2 + \dots . a_{m1}x_m \geq 1 \\ a_{12}x_1 + a_{22}x_2 + \dots . a_{m2}x_m \geq \\ a_{1n}x_1 + a_{2n}x_2 + \dots . a_{mn}x_m \geq 1 \\ x_i = \frac{p_i}{V} \geq 0; i = 1, 2, \dots, \mathrm{m} \end{array}\right\} \quad (8)$$

Similarly, player B has a similar problem with the inequalities of the constraints reversed, i.e. minimizing the expected loss. Since minimizing V is equivalent to maximizing $\frac{1}{V}$Therefore, the resulting linear programming problem can be stated as:

Maximize $Z_q \left(= \frac{1}{V}\right) = y_1 + y_2 + \dots + y_n$

Subject to the constraints \

$$\left.\begin{array}{l} a_{11}y_1 + a_{12}y_2 + \dots . + a_{1n}y_n \leq 1 \\ a_{12}y_1 + a_{22}y_2 + \dots . + a_{2b}y_n \leq 1 \\ a_{m1}y_1 + a_{m2}y_2 + \dots . + a_{mn}y_n \leq 1 \\ y_1, y_2, \dots, y_n \geq 0 \\ y_j = \frac{q_j}{V} \geq 0; j = 1, 2, \dots, \mathrm{n} \end{array}\right\} \quad (9)$$

It may be noted that the linear programming problem of player B is the dual linear programming problem of player A and vice versa. Therefore, the dual problem can be solved from the primal simplex table. Since for both players $Z_p = Z_q$, the expected gain to player A in the game will be exactly equal to the expected loss to player B.

It should be noted that the linear programming technique requires all variables to be non-negative. Therefore, to obtain a non-negative value V of the game, the problem data, i.e. a_{ij} = 1, the payoff table should all be non-negative. If there are some negative elements in the payoff table, a constant to every element in the table must be added to make the smallest element zero; the solution to this new game will give an optimal mixed strategy for the original game. The original game's value equals the new game's value minus the constant (Sharma, 2008).

3.3. Empirical Review

In their work, Eme and Anyata (2015) aim to measure the marginal effect of a key variable, such as a hydropower generation/ water supply or railway system, upon a set of relevant policy variables, such as Economic and Environmental Impact Analysis. Only the impacts of the socioeconomic subsystem (E) and geographic-demographic subsystem (G) upon the environmental subsystem (M) are assessed. Therefore, the environmental profile is the central pivot of the analysis.

A cost-benefit analysis was criticized for several reasons, such as neglect of the equity criteria, not incorporating uncertainties, etc. In the environmental evaluation survey, it is evident that in the neoclassical or cost-benefit analysis framework, the evaluation of environmental commodities has to be based on market prices. When market prices do not exist for environmental commodities, artificial prices, e.g., shadow prices, must be calculated to ensure an operational result.

3.3.1. Comments

(i) Their methodology involved an integrated structure of an Economic-environmental survey, which was investigated in greater detail. (ii) In conclusion, several methods developed and employed so far cannot be regarded as satisfactory evaluation techniques for an operational environmental policy analysis. (iii) Intangible and incommensurable effects are also very hard to incorporate in all these methods. (iv) The conclusion is justified that any attempt to transform an unpriced impact into a single dimension must fail unless corrected with the Bayesian decision model or Markov chains, which could address uncertainties, equity, risk, time effect, poor data availability, etc.

3.3.2. Research Gap

(i) The climate change variability analysis where Game and Bayesian theory were compared while considering multipurpose/multi-objectives of 10 × 10 matrix was not covered by their research work, which is the gap. Eme (2012) stated in his paper that the principal objective is to find a decision strategy that maximizes the expected return or minimizes the cost.

The paper applies Markovian decision theory in multipurpose/multi-objective dam development optimization. The problem investigated was a decision problem on how to apportion (allocate) a development fund to optimize the returns under the worst conditions of conflict. It considers a hypothetical case where N100 million will be spent on a multipurpose/multi-objective water resources development project. The interest purposes are irrigation, hydroelectric power generation, and water supply. The returns (objectives) to be optimized in stages as multi-stage decision problems are economic efficiency, regional redistribution and social wellbeing, and a benefit (return) study of the three purposes under each of the three objectives was carried out. In conclusion, policy five yields the highest expected yearly benefit of N9.12 million under the worst conflicting conditions.

3.3.3. Comments/Research Gap

(i) The research paper was on three purposes/objectives to yield the highest expected benefit returns. (ii) It did not consider other purposes/objectives for full capacity utilization of the river basin using Bayesian and Game theory variability as a climate change solution in the Anambra-Imo basin, which is the gap.

Onutu (2012) stated that Nigeria is abundantly endowed with renewable and non-renewable energy resources like Hydro, Solar, Wind, Oil, Gas, Coal, and Tar Sand, etc. over the years, successive governments therefore, approach the development and exploitation of these resources in a very skewed manner in favour of the Oil and Gas sub sector to the detriment of the other resources and the environment.

The existing public structure recognizes the need to develop and safely exploit these resources. It places the responsibilities for energy matters in four different government organizations, each addressing a specific energy resource type. As prescribed by the enabling law, the Energy Commission of Nigeria (ECN) is the apex body charged with developing, coordinating and implementing all energy-related energy policies.

With this mandate, the ECN developed the country’s first National Energy Policy (NEP) in 1991 and was approved by the Federal Executive Council in 2003 after almost twelve years. This paper studies this policy as it concerns Energy Sources: Oil, Natural Gas, Hydro and Wind, Energy Utilization, Electricity and Transportation, Energy issues, Environmental and Energy Efficiency and Conservation and assesses the level of adherence to the provisions of the National Energy Policy.

3.3.4. Comments/Research Gap

(i) His work stated that Nigeria has renewable and nonrenewable energy sources for clean energy. (ii) The work did not address climate change solutions in river basin management. Eme (2015) applied the Exhaustive Enumeration method of Markovian Decision theory and considered N12.3 billion released from 2007 to 2011 for capital projects to Anambra/ Imo River Basin Development Authority, Nigeria, under the supervision of the Federal Ministry of Water Resources in Nigeria, with the sole aim at optimization of allocation to various projects and maximization of expected revenue to the Authority.

The developmental projects are Irrigation, Water Supply, Hydro-electric Power Generation, Flood Control, Drainage, Navigation, Recreation/Tourism and Erosion Control. The objectives optimized in stages as a multi-stage decision problem are Economic Optimization, Federal, Regional State and Local Economic Redistribution, Social wellbeing, Youth Employment and Environmental Quality Improvement. The problem then becomes how to allocate (apportion) the ₦12.3 billion limited development funds among the various projects to optimize the returns even under the worst conflict situation.

The methodology involves methods and experiments, and data were collected from Anambra/ Imo River Basin Authority, Owerri, Ministries and Parastatals. From the interpretation of the results of the experiments, Policy 10 yields the largest expected yearly revenue of ₦2.7 billion under the worst conflict conditions.

The developmental projects should be apportioned by the planning and management engineer as follows: irrigated Agriculture (₦0.24 billion), water supply (N.54 billion), Hydroelectric Power generation (₦0.84 billion), Flood Control (₦1.08 billion), Drainage (₦1.42 billion), Navigation (₦1.57 billion), Recreation (₦2.82 billion) and Erosion Control (₦3.8 billion) for the optimal solution in maximization of investment on the River Basin which has limited fund allocated to it from Federal budget.

3.3.5. Comments/Research Gap

(i) His paper was on Markovian decision theory. (ii) This research was on variability analysis Bayesian and Game theory in climate change solutions for full capacity utilization at the Anambra-Imo River basin development authority, which is the gap. Bukar et al. (2018) researched the existing structure/delineation of the coverage areas in Nigeria River Basin Development Authorities (RBDAs), emphasizing sharing the largest inland drainage system in Komadugn in Yobe state.

They identified structural defects and operational challenges in developing the Komadugn Yobe basin area. They used data from the satellite images of the Basin area with topographic and hydrological maps of the study area. They concluded that there is a need for a fair, judicious and sustainable allocation of water resources among the competing sectors, constituent regions and states. They continued that without a theoretical reversal of the operating principles and maintenance schedules, and extreme environmental damage will result without desirable economic and agronomic benefits. They stated that the implementation of projects should consider the stream ordering principles for greater effectiveness in realizing the objectives.

3.3.6. Comments/Research Gaps

(i) They considered operational challenges that can be resolved by reviewing the existing number and structure of the areas of jurisdiction of the River Basin Authorities.

(ii) Their work did not consider climate change factors like flooding, drought, erosion, brown energy use and how they affect the river basin, which is the research gap.

4. Methodology

The south eastern river basin covers almost all of the south eastern states. The methodology involves using Bayesian decision analysis of Enugu, Ebonyi, Anambra, Abia, and the Imo States of Nigeria for optional capacity utilization of the resources to effect climate variability solutions at the basin. Game decision theory was used to determine the optimal strategies for both players.

The data used for both analyses were generated from the Bill of Engineering Measurement and Evaluation (BEME), descriptive, experimental model size and simulation modelling solution techniques.

4.1. Data Collection for the Experiment and Determination of Benefits to Various Purpose/Objectives in South-Eastern River Basin, Nigeria

The main objectives in a multi-objective water resources development considered in this research are (i) Economic efficiency, (ii) Federal Economic Redistribution, (iii) Regional Economic Redistribution,

(iv) State Economic Redistribution, (v) Local Economic Redistribution, (vi) Social Wellbeing, (vii) Youth Empowerment, (viii) Environmental Quality Improvement, (ix) Gender Equality, (x) Security Improvement.

(a) Irrigation = improvement in land value and yields from agricultural activities.
(b) Hydro-electric power generation is based on net returns from selling electrical energy.
(c) Water supply, which is the net return from the sale of water
(d) Water Transport/Navigation,
(e) Drainage/ Dredging of rivers – value of areas of land drained and reclaimed.
(f) Flood control: value of land area protected from flood.
(g) Recreation / Tourism – the area of land value designated for recreation purposes.
(h) Erosion control: area of land reclaimed and protected from erosion menace
(i) Plantation / Forestry: plantation intended to reduce carbon emissions from fossil fuel in the environment
(j) Reservoirs / Gullies will be used to encourage the generation of hydroelectric power.

4.2. Experimental Model Size

This model constitutes the sample size for full capacity utilization of the river basin as a climate change solution. The independent variables are the development of (i) Irrigated agriculture (ii) Hydro-electric power generation, (iii) Water supply, (iv). Navigation, (v) Drainage/ Dredging, (vi). Flood control, (vii) Recreation / Tourism, (viii) Erosion control, (ix) Plantation / Forestry, (x) Reservoir/Gullies.

The objectives (benefits) as dependent variables are (i) Economic efficiency (optimization), (ii) Federal Economic Redistribution, (iii) Regional Economic Redistribution, (iv) State Economic Redistribution, (v) Local Economic Redistribution, (vi) Social Wellbeing, (vii) Youth Empowerment, (viii) Environmental Quality Improvement, (ix) Gender Equality, (x) Security Improvement.

The areas of investment in Plantation/Forestry will help to restore the ecosystem damaged by human activities on the earth's planet within the area. Other areas that will mitigate the effect of climate change include the reduction of greenhouse gas emissions in land, air and waterways; Drainage/Dredging of rivers to encourage the confinement of following rivers to their channels to avoid flooding, erosion, hydropower, and other purposes as identified.

4.3. Simulation Modeling Solution Techniques

The data were derived from Bills of Engineering Measurement and Evaluation (BEME) and calculated based on the various purposes, objectives, and net benefits of 10 (10 matrix values).

4.4. Bill of Engineering Measurement and Evaluation (BEME)

The basis for the calculation of BEME was based on various parameters of the area of land to be irrigated, estimated cost of irrigation per km^2, estimated improved market value of the facilities, benefits return of each unit and net benefit return. Others are hydro-electric power generation on units of kwh per year to be generated, unit cost of energy generation, estimated improved market value, benefit return of each investment and net benefit return, etc., savings on road users cost, enhanced property value, rent and rate are also integrated to calculate the benefits for each multipurpose project.

4.5. Validity, Reliability and Limitations of BEME Data used

The data and information for the Bill of Engineering Measurement and Evaluation (BEME) were collected from the Federal Office of Statistics, Ministry of Works and Housing, Ministry of Power and Energy and Local Government Authorities in the south eastern states where the river basin was located. For various purposes, the project was located in the proposed area where the development facilities existed. The BEME were limited to the south eastern river basin.

5. Analysis and Discussion of Results

5.1. Summary of Net Benefits Multipurpose under Various Multi-Objectives

Table 1. Summary of net benefits for all the objectives against the purposes in 5 billion Naira

S/N	Purpose	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
(1)	Irrigated Agriculture	3.65	4.84	6.36	3.60	3.44	4.37	4.05	4.22	1.12	8.73
(2)	Hydro-electric power generation	13.38	7.55	9.60	9.68	9.29	5.46	6.05	6.39	1.37	10.95
(3)	Water supply	4.54	4.34	6.04	3.78	3.52	4.56	4.22	4.37	1.13	9.13
(4)	Navigation	8.30	5.83	10.46	8.19	8.24	11.39	10.96	12.20	3.33	25.77
(5)	Drainage/ Dredging	17.21	6.01	12.26	3.68	6.08	8.96	11.51	10.83	3.00	21.96
(6)	Flood control	19.43	5.58	10.20	3.39	1.55	8.68	10.32	11.35	2.90	22.12
(7)	Recreation / Tourism	16.93	3.94	10.36	3.42	3.33	10.57	11.33	12.25	3.33	25.94
(8)	Erosion control	13.91	3.01	10.27	3.15	3.26	9.56	7.13	8.72	2.21	16.78
(9)	Plantation / Forestry	14.01	6.83	8.08	6.40	6.59	8.96	7.66	8.40	2.26	18.08
(10)	Reservoir/ Gullies	82.72	5.66	12.16	3.36	3.48	19.99	20.54	20.71	5.77	41.23

B_1= Economic efficiency,
B_2 = Federal Economic Redistribution,
B_3 = Regional Economic Redistribution,
B_4= State Economic Redistribution,
B_5 = Local Economic Redistribution,
B_6 = Social Well-being,
B_7 = Youth Empowerment,
B_8 = Environmental Quality Improvement,
B_9 = Gender Equality,
B_{10} = Security

Discussion of Results in Table 1:

Table 1 explains the summary results of calculating net benefits from the Bill of Engineering Measurement and Evaluation (BEME) in billions of Naira.

1. Under irrigation agriculture, the highest benefit, N8.73 billion, was in security, while the least benefit was N1.12 billion in gender equality. On Hydro-electric Power Generation, Economic Efficiency has the highest value of ₦13.38 billion while the lowest value of ₦1.37 billion was on Gender Equality.
2. Under the purpose of Reservoir and Gullies, the highest benefit of ₦82.72 billion was from the objective of Economic Efficiency, and the lowest was ₦3.36 billion on State Economic Redistribution.
3. In other purposes, the Net benefits have the highest from objectives on Security with the following values: ₦9.13 billion from Water Supply, ₦25.77 billion from Navigation, ₦21.96 billion from Drainage/Dredging, ₦22.12 billion from Flood Control, ₦25.94 billion from Recreation/Tourism; ₦16.78 billion from Erosion Control and ₦18.08 billion from Plantation/Forestry.
4. The lowest Net benefits were from the objectives on Gender Equality. Others are the following: ₦1.13 billion from Water Supply; ₦3.33 billion from Navigation; ₦3.00 billion from Drainage/Dredging; ₦2.90 billion from Flood Control; ₦3.33 billion from Recreation/Tourism; ₦2.21 billion from Erosion Control and ₦2.26 billion from Plantation/Forestry.

5.2. Bayesian Decision Model Simulation Based on Courses of Action

Using the Bayesian Decision Analysis, the prior probability was derived from the benefits and used in the analysis for the previous prediction, i.e. states of nature probabilities: $N_1 = 0.02$, $N_2 = 0.07$, $N_3 = 0.03$, $N_4 = 0.04$, $N_5 = 0.09$, $N_6 = 0.10$, $N_7 = 0.09$, $N_8 = 0.07$, $N_9 = 0.08$, $N_{10} = 0.41$.

5.2.1. Calculation of Likelihood Forecast of Probabilities

Table 2. The likelihood forecast of probability estimated from the various courses of action for net benefits

States of Nature	Courses of Action									
	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9	B_{10}
N_1	0.08	0.11	0.14	0.08	0.08	0.10	0.09	0.10	0.02	0.20
N_2	0.17	0.09	0.12	0.12	0.12	0.07	0.07	0.08	0.02	0.14
N_3	0.10	0.10	0.13	0.08	0.08	0.10	0.09	0.10	0.02	0.20
N_4	0.08	0.05	0.10	0.08	0.08	0.11	0.10	0.12	0.03	0.25
N_5	0.17	0.06	0.12	0.03	0.06	0.09	0.11	0.11	0.03	0.22
N_6	0.20	0.06	0.11	0.03	0.02	0.09	0.11	0.12	0.03	0.23
N_7	0.17	0.04	0.10	0.04	0.03	0.10	0.11	0.12	0.03	0.26
N_8	0.18	0.04	0.13	0.04	0.04	0.12	0.09	0.11	0.03	0.22
N_9	0.16	0.08	0.09	0.07	0.07	0.10	0.09	0.10	0.03	0.21
N_{10}	0.38	0.02	0.06	0.01	0.02	0.09	0.10	0.10	0.03	0.19

Where the courses of action are;

- N_1 = Irrigation Agriculture,
- N_2 = Hydro-electric Power Generation,
- N_3 = Water Supply,
- N_4 = Navigation/Water Transport,
- N_5 = Drainage/Dredging,
- N_6 = Flood Control,
- N_7 = Recreation/Tourism,
- N_8 = Erosion Control,
- N_9 = Plantation/Forestry,
- N_{10} = Reservoir/Gullies

Where the states of nature are;

- B_1 = Economic efficiency,
- B_2 = Federal Economic Redistribution,
- B_3 = Regional Economic Redistribution,
- B_4 = State Economic Redistribution,
- B_5 = Local Economic Redistribution,
- B_6 = Social Well-being,
- B_7 = Youth Empowerment,
- B_8 = Environmental Quality Improvement,
- B_9 = Gender Equality,
- B_{10} = Security

Discussion of Results in Table 2:

Table 2 shows the likelihood forecast probabilities from various courses of action. These probabilities were used to calculate the Joint probability outcomes on the first iteration to determine the Marginal probability outcomes. The next step is calculating the Expected Monetary Values (EMVs) using the Prior Probabilities for the States of Nature.

Table 3. Calculation of Expected Monetary Values (EMVs) at First Iteration

States of Nature	**Prior Probability**	**Conditional Net Benefits Course of Action in Billions of Naira**										**Expected Net Benefits in Billions of Naira Course of Action**									
		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
N_1	0.02	3.65	4.84	6.36	3.60	3.44	4.37	4.05	4.22	1.12	8.73	0.073	0.0968	0.1272	0.072	0.0688	0.0874	0.081	0.0844	0.0224	0.1746
N_2	0.07	13.38	7.55	9.60	9.68	9.29	5.46	6.05	6.39	1.37	10.95	0.9366	0.5285	0.672	0.6776	0.6503	0.3822	0.4235	0.4473	0.0959	0.7665
N_3	0.03	4.54	4.34	6.04	3.78	3.52	4.56	4.22	4.37	1.13	9.13	0.1362	0.1302	0.1812	0.1134	0.1056	0.1368	0.1266	0.1311	0.0339	0.2739
N_4	0.04	8.30	5.83	10.46	8.19	8.24	11.39	10.96	12.20	3.33	25.77	0.332	0.2332	0.4184	0.3276	0.3296	0.4556	0.4384	0.488	0.1332	1.0308
N_5	0.09	17.21	6.01	12.26	3.68	6.08	8.96	11.51	10.83	3.00	21.96	1.5489	0.5409	1.1034	0.3312	0.5472	0.8064	1.0359	0.9747	0.27	1.9764
N_6	0.10	19.43	5.58	10.20	3.39	1.55	8.68	10.32	11.35	2.90	22.12	1.943	0.558	1.02	0.339	0.155	0.868	1.032	1.135	0.290	2.212
N_7	0.09	16.93	3.94	10.36	3.42	3.33	10.57	11.33	12.25	3.33	25.94	1.5237	0.3546	0.9324	0.3078	0.2997	0.9513	1.0197	1.1025	0.2997	2.3346
N_8	0.07	13.91	3.01	10.27	3.15	3.26	9.56	7.13	8.72	2.21	16.78	0.9737	0.2107	0.7189	0.2205	0.2282	0.6692	0.4991	0.6104	0.1547	1.1746
N_9	0.08	14.01	6.83	8.08	6.40	6.59	8.96	7.66	8.40	2.26	18.08	1.1208	0.5464	0.6464	0.512	0.5272	0.7168	0.6128	0.672	0.1808	1.4464
N_{10}	0.41	82.72	5.66	12.16	3.36	3.48	19.99	20.54	20.71	5.77	41.23	33.9972	2.3206	0.8856	1.3776	1.4268	8.1959	8.4214	8.4911	2.3657	6.9043
		Expected monetary values (EMVs)										42.5851	5.5199	6.7055	4.2787	4.3364	13.2496	13.6904	14.1365	3.8463	28.2941

5.2.2. Determination of Expected Monetary Value (EMVs) at First Iteration

The Expected Monetary Values (EMVs) or Expected Utility explains the criteria for various courses of action (alternatives) under risk. The EMV is the weighted sum of possible payoffs from each alternative. It is obtained by adding up the payoffs of each course of action multiplied by the probabilities associated with each state of nature. This was calculated and shown in Table 3. The Maximum Expected Monetary Value (EMV*) = ₦42.5851 billion on Economic Efficiency is the optimal course of action with other optimal course of action with other objectives to be considered for maximum benefits.

Where the states of nature are;

S_1 = Economic efficiency,
S_2 = Federal Economic Redistribution,
S_3 = Regional Economic Redistribution,
S_4 = State Economic Redistribution,
S_5 = Local Economic Redistribution,
S_6 = Social Well-being,
S_7 = Youth Empowerment,
S_8 = Environmental Quality Improvement,
S_9 = Gender Equality,
S_{10} = Security

The calculation of expected monetary values will be repeated for second iteration after the completion of the first iteration process for the second iteration before the third iteration process starting with the Expected Monetary values as third iterations as shown in Table 4.

5.2.3. Determination of Expected Monetary Values (EMV_S) at third iteration

Table 4 was generated after the completion of the second iteration process to determine the prior probabilities used for its computation.

Table 4. Calculation of Expected Monetary Values (EMVs) at third (3rd) iteration

States of Nature	Prior Probability $P(N_j)$	Conditional Net Benefits Course of Action in Billions of Naira										Expected Net Benefits in Billions of Naira Course of Action									
		S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
N_1	0.0017	3.65	4.84	6.36	3.60	3.44	4.37	4.05	4.22	1.12	8.73	0.0062	0.0082	0.0108	0.0061	0.0058	0.0074	0.0069	0.0072	0.0019	0.0148
N_2	0.0024	13.38	7.55	9.60	9.68	9.29	5.46	6.05	6.39	1.37	10.95	0.3211	0.1812	0.2304	0.2323	0.2230	0.1310	0.1452	0.1534	0.0329	0.2628
N_3	0.0040	4.54	4.34	6.04	3.78	3.52	4.56	4.22	4.37	1.13	9.13	0.0182	0.0174	0.0242	0.0151	0.0141	0.0182	0.0502	0.0175	0.0045	0.0365
N_4	0.0043	8.30	5.83	10.46	8.19	8.24	11.39	10.96	12.20	3.33	25.77	0.0357	0.0251	0.0450	0.0352	0.0354	0.0490	0.0471	0.0525	0.0143	0.1108
N_5	0.0345	17.21	6.01	12.26	3.68	6.08	8.96	11.51	10.83	3.00	21.96	0.5937	0.2073	0.4230	0.1270	0.2098	0.3091	0.3971	0.03736	0.1035	0.7576
N_6	0.0532	19.43	5.58	10.20	3.39	1.55	8.68	10.32	11.35	2.90	22.12	1.0337	0.2969	0.5426	0.1803	0.0825	0.4618	0.5490	0.6038	0.1543	1.1768
N_7	0.0345	16.93	3.94	10.36	3.42	3.33	10.57	11.33	12.25	3.33	25.94	0.5841	0.1359	0.3574	0.1180	0.1149	0.3647	0.3909	0.4226	0.1149	0.8949
N_8	0.0276	13.91	3.01	10.27	3.15	3.26	9.56	7.13	8.72	2.21	16.78	0.3839	0.0831	0.2835	0.0869	0.0900	0.2639	0.1968	0.2407	0.0610	0.4631
N_9	0.0281	14.01	6.83	8.08	6.40	6.59	8.96	7.66	8.40	2.26	18.08	0.3937	0.1919	0.2270	0.1798	0.1852	0.2518	0.2152	0.2360	0.0635	0.5080
N_{10}	0.7881	82.72	5.66	2.16	3.36	3.48	19.99	20.54	20.71	5.77	41.23	63.3493	4.4606	1.7023	2.6480	2.7426	15.7541	16.1876	16.3216	4.5473	32.4934
		Expected Monetary Values (EMVs) =										68.7196	5.6076	3.8462	3.6287	3.7033	17.611	18.1527	18.4289	5.0981	36.7187

Discussion of Results in Table 4

(i) The information in Table 4 shows that the expected monetary values of each of the objectives for the third iteration are: ₦68.7196 billion for economic efficiency; ₦5.6076 billion for federal economic redistribution; ₦3.8462 billion for regional economic redistribution; ₦3.6287 billion for state economic redistribution; ₦3.7033 billion for local economic redistribution; ₦17.611 billion for social wellbeing; ₦18.1527 billion for youth empowerment; ₦18.4289 billion for environmental quality improvement; ₦5.0981 billion for gender equality; and ₦36.7187 billion for security. (ii) The policy algorithm of the Bayesian Model at the third iteration of EMVs is an improvement from the second iteration. (iii). The maximum Expected Monetary Value (EMV*) = ₦68.7196 billion for economic efficiency. (iv) This shows that the maximum Expected Monetary Value (EMV*) increases with the information provided by an expert or consultant.

Referring to the data on Table 14, the maximum benefit for each state of nature is used to calculate the Expected Profit with Perfect Information (EPPI) = 0.0017(8.73) + 0.024(13.38) + 0.004 (9.13) + 0.0043 (25.77) + 0.0345 (21.96) + 0.0532 (22.12) + 0.0345(25.94) + 0.0276 (16.78) + 0.0281(18.08) + 0.7881 (82.92) = ₦69.633 The Expected Value of Perfect Information (EVPI) = EPPI – EMV = ₦69.633 - ₦68.7196 billion= ₦0.9134 billion For each forecast result, the Prior and Posterior probabilities are calculated for the iteration process to determine the optimal values for discussion of experimentation of the river basin resources utilization and climate variability using the Bayesian model in 5.2.4.

5.2.4. Discussion of Experimentation on Optimization of River Basin Resources Utilization and Climate Variability Analysis Using the Bayesian Model

1. The Bayesian Decision Model optimization is best for situations of uncertainty, i.e., the state of nature, which is the future conditions (also called consequences, events, or scenarios) associated with climate change or climate variability.

2. The Bayesian theory describes the magnitude of difference between alternative actions. It provides a variety of estimates for consideration, shown by the result of the policy iteration algorithm on the third iteration.

3. The full capacity utilization of river basin assets of Irrigation Agriculture, Hydro-electric power generation, Water supply, Navigation, Drainage/Dredging, Flood Control, Recreation/Tourism, Erosion Control, Plantation/Forestry, and Reservoir/Gullies are the veritable tools to combat climate change impacts on the river basin.

4. The Bayesian decision theory prioritizes development projects according to the degree of return from expected monetary values and the amount of money released to the river basin. The EMV* with additional information or data on climate projections and scenarios will yield ₦68.72 billion compared to ₦42.59 billion without data on the first iteration. A balance of N26.13 billion was realized with additional information.

5. The BDT also shows the order of investment if funds are scarce for capital development projects based on the highest benefits from irrigation agriculture.

6. Implementing the ten (10) purposes with the ten (10) objectives will often champion the course of a green revolution in the South-Eastern River basin, Nigeria.

7. When the maximum expected monetary value of ₦68.72 billion and the money released of ₦12.504 billion are deducted from the benefits, the river basin will have an excess of ₦56.216 billion for future mitigation of climate variability impacts.

Table 5. Game theory model analysis based on the hypothetical net benefits

	B_1	**B_2**	**B_3**	**B_4**	**B_5**	**B_6**	**B_7**	**B_8**	**B_9**	**B_{10}**	**Minimum**
A_1	3.65	4.84	6.36	3.60	3.44	4.37	4.05	4.22	1.12	8.73	1.12
A_2	13.38	7.55	9.60	9.68	9.29	5.46	6.05	6.39	1.37	10.95	1.37
A_3	4.54	4.34	6.04	3.78	3.52	4.56	4.22	4.37	1.13	9.13	1.13
A_4	8.30	5.83	10.46	8.19	8.24	11.39	10.96	12.20	3.33	25.77	3.33
A_5	17.21	6.01	12.26	3.68	6.08	8.96	11.51	10.83	3.00	21.96	3.00
A_6	19.43	5.58	10.20	3.39	1.55	8.68	10.32	11.35	2.90	22.12	2.90
A_7	16.93	3.94	10.36	3.42	3.33	10.57	11.33	12.25	3.33	25.94	3.33
A_8	13.91	3.01	10.27	3.15	3.26	9.56	7.13	8.72	2.21	16.78	2.21
A_9	14.01	6.83	8.08	6.40	6.59	8.96	7.66	8.40	2.26	18.08	2.26
A_{10}	82.72	5.66	12.16	3.36	3.48	19.99	20.54	20.71	5.77	41.23	**3.36**
Maximum	**82.92**	**7.55**	**12.26**	**9.68**	**9.29**	**19.99**	**20.54**	**20.71**	**5.77**	**41.23**	↑
Maximin value = 5.77 Minimax value = 3.36									**Maximin**↑		**Minimax**

5.3. The Optimal Solution for Game Theory Analysis

In order to determine game decision theory for both players, table 5 shows the purposes and net benefits of determining maximin and minimax. There is variance in maximum and minimum values, which shows that there is no saddle point, which led to the use of the linear programming method of the game theory model for the analysis in 5.3.1 and 5.3.2.

The results from the optimal solution for Game decision theory for both players are

5.3.1. For Player B

$x_1 = 0.021$, $x_2 = 0.023$, $x_3 = 0.014$, $x_4 = 0.013$, $x_5 = 0.015$, $x_6 = 0.017$, $x_7 = 0.012$, $x_8 = 0.024$, $x_9 = 0.01$, $x_{10} = 0.032$ and $Z_p = 0.181 = \frac{1}{V}$

$$\text{Since } Z_p = \frac{1}{V} = 0.181, V = \frac{1}{Z_p} = \frac{1}{0.181} = 5.52$$

From Table 2 of the Player table, the value of the game, V, is expected between maximin 3.36 and minimax 5.77. The above value of V = 5.52 confirms the authenticity of this result. Converting these solution values back into the original variables, we have,

$$x_n = \frac{P_n}{V}, \qquad P_n = x_n V$$

For n = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10.

$P_1 = x_1 \times V = 0.021 \times 5.52 = 0.1160$; $P_2 = x_2 \times V = 0.023 \times 5.52 = 0.1270$

$P_3 = x_3 \times V = 0.014 \times 5.52 = 0.0774$; $P_4 = x_4 \times V = 0.013 \times 5.52 = 0.0719$

$P_5 = x_5 \times V = 0.015 \times 5.52 = 0.0829$; $P_6 = x_6 \times V = 0.017 \times 5.52 = 0.0939$

$P_7 = x_7 \times V = 0.012 \times 5.52 = 0.0663$; $P_8 = x_8 \times V = 0.024 \times 5.52 = 0.1325$

$P_9 = x_9 \times V = 0.01 \times 5.52 = 0.0553$; $P_{10} = x_{10} \times V = 0.032 \times 5.52 = 0.1767$

5.3.2. For Player A

The Final Simplex optimization result determines optimal strategies for Player A from the reduced cost row (i.e., the Zj – Cj row). These are;

$$Y_1 = S_1 = 0.018 Y_2 = S_2 = 0.025$$
$$Y_3 = S_3 = 0.011 Y_4 = S_4 = 0.014$$
$$Y_5 = S_5 = 0.013 Y_6 = S_6 = 0.019$$
$$Y_7 = S_7 = 0.012 Y_8 = S_8 = 0.023$$
$$Y_9 = S_9 = 0.011 Y_{10} = S_{10} = 0.035$$

Total sum (Z_q) = $0.018 + 0.025 + 0.011 + 0.014 + 0.013 + 0.019 + 0.012 + 0.023 +$

$$0.011 + 0.035 = 0.181$$

$$Z_q = 0.181 = \frac{1}{V} \Rightarrow V = \frac{1}{Z_q} = \frac{1}{0.181} = 5.52$$

This corresponds with the value of the game V = 5.52 in optimal strategies for Player B. Also, converting these solution values back into the original variables,

$$q_1 = Y_1 \times V = 0.018 \times 5.52 = 0.0994$$
$$q_2 = Y_2 \times V = 0.025 \times 5.52 = 0.1380$$
$$q_3 = Y_3 \times V = 0.011 \times 5.52 = 0.0608$$
$$q_4 = Y_4 \times V = 0.014 \times 5.52 = 0.0774$$
$$q_5 = Y_5 \times V = 0.013 \times 5.52 = 0.0714$$
$$q_6 = Y_6 \times V = 0.019 \times 5.52 = 0.1050$$
$$q_7 = Y_7 \times V = 0.012 \times 5.52 = 0.0663$$
$$q_8 = Y_8 \times V = 0.023 \times 5.52 = 0.1270$$
$$q_9 = Y_9 \times V = 0.011 \times 5.52 = 0.0608$$
$$q_{10} = Y_{10} \times V = 0.035 \times 5.52 = 0.1934$$

Hence, the probabilities of using strategies by both players are:

Player A = (0.0994, 0.138, 0.0608, 0.0774, 0.0719, 0.1050, 0.0663, 0.127, 0.0608, 0.1934)

Player B = (0.1160, 0.127, 0.0774, 0.0719, 0.0829, 0.0939, 0.0663, 0.1326, 0.0553, 0.1767).

5.3.3. Discussion of Experimentation on Optimization of River Basin Resources Utilization and Climate Variability Analysis using Game Theory

Full Capacity Utilization using Game Theory in the south-eastern river basin of Nigeria involves a particular strategy by which a player optimizes gains or losses without knowing the competitor's strategy to maximize gains or minimize losses in climate variability. The mixed strategies are used because the courses of action were selected on a particular occasion with some fixed probability. There is a probabilistic situation where the player's objective is to maximize expected gains or minimize expected losses by choosing pure strategies with fixed probabilities. A matrix was developed to determine the probabilities for the multipurpose/multi-objective of Player A and Player B. The probabilities of selecting A_i for (i = 1, 2, 3, 4, 5, 6, . . . ,10) was q_i for (i = 1, 2, 3, 4, 5, 6, . . . ,10) and the strategy of selecting B_i for (i = 1, 2, 3, 4, 5, 6, . . . ,10) was p_i for (i = 1, 2, 3, 4, 5, 6, . . . ,10). The problem of Player A was minimized, while the problem of Player B was maximized using a linear programming simplex method to determine the optimal solution. The result of the optimal strategies shows that the value of the game (V) = 5.52, which lies between the maximin value (3.36) and the minimax value (5.77). The optimal strategies for Player A were determined from the reduced cost row (i.e. Z_j - $C_{j\ row}$). In contrast, the optimal strategies for Player B were determined from the amount column resulting from the exchange segment. The resource allocation strategies for the game based on ₦12.504 billion released for capital projects to the south-eastern river basin from 2015-2020 for the purposes are ₦1.243 billion for Irrigated agriculture, ₦1.726 billion for hydro-electric power generation, ₦0.76 billion for Water supply; ₦0.968 billion for Navigation; ₦0.899 billion for Drainage/Dredging; ₦1.313 billion for Flood control; ₦0.829 billion for Recreation/Tourism; ₦1.588 billion for Erosion control; ₦0.760 billion for

Plantation/Forestry; and ₦2.418 billion for Reservoir/Gullies. The optimal strategies for the various objectives/ benefits based on money released for capital projects from 2015-2020 applying the probabilities from the Game theory model analysis, are ₦1.45 billion for Economic efficiency, ₦1.588 billion for Federal economic redistribution, ₦0.968 billion for Regional economic redistribution; ₦0.899 billion for State economic redistribution; ₦1.037 billion for Local economic redistribution; ₦1.174 billion for Social wellbeing; ₦0.829 billion for Youth empowerment; ₦1.658 billion for Environmental quality improvement; ₦0.692 billion for Gender equality and ₦2.209 billion for Security. When the allocation is apportioned under the worst situation of conflicting purposes/objectives, the financial benefits achievable will be ₦12.504 ×5.52 = ₦69.022 billion. The Maximum Expected Monetary Value (EMV*) from the Bayesian theory on the third iteration (with additional information) is ₦68.7196 billion, which gives a margin of ₦69.022 – ₦68.7196 = ₦0.3024billion.This result shows that the strategy for game theory is higher than that of Bayesian theory by ₦0.3024 billion. When the allocation of ₦12.504 was deducted from the amount realized from full capacity utilization, the river basin will have a surplus of ₦56.518 billion for investment in the river basin. Implementing these optimal Game theory strategies will assist in mitigating the effect of climate variability irrespective of the conditions of conflicts for improved and integrated planning and management of adequate climate change adaptation, which has a global potential contribution to multiple sustainable challenges in the river basin. Assuming the ₦12.504 billion was borrowed at 6 % interest for 5-year period, the total amount to be repaid with compounded interest will be ₦12.504 × (1.06^5) = ₦16.7332 billion. When this is deducted from the money generated from Bayesian (₦68.7196 billion) and Game (₦69.022 billion) Theories, we have ₦51.9864 billion and ₦52.2888 billion, respectively, as the profit margin for the period.

5.4. Development of Blueprint for South Eastern Nigeria River Basin

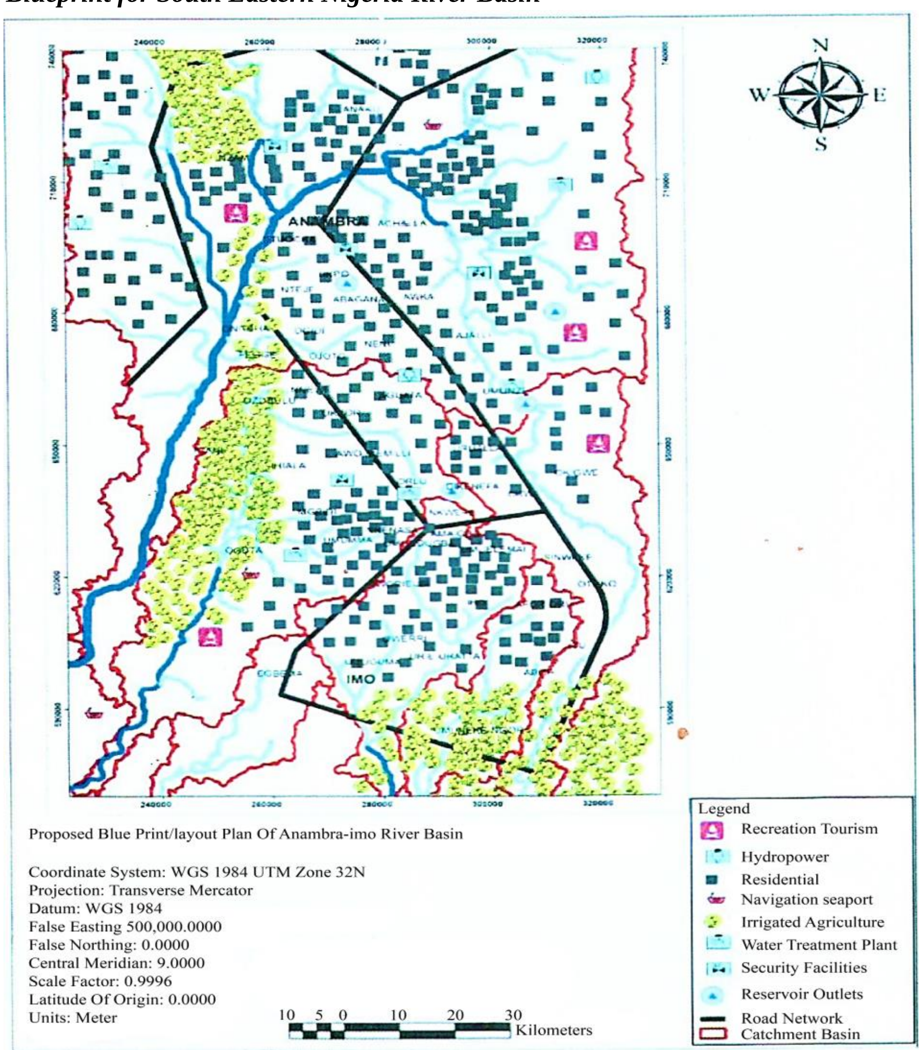

Fig. 3 Blueprint/layout plan of south-eastern Nigeria river basin

5.5. Discussion of Results on Optimization of Capacity Utilization Blueprint/Layout for Green Revolution in South-Eastern River Basin

The data obtained, and computation using Bayesian and Game theories model analysis led to the development of a Blueprint/Layout for the green revolution to checkmate Climate Variability problems identified in the south-eastern river basin. The allocation of available funds will encourage optimal solution strategies and the best situation of uncertainty, i.e., the state of nature, which is the future conditions, consequences, events, or scenarios associated with climate change. The blueprint was developed from the design of the layout plan at the river basin. These include;

5.5.1. Irrigation Agriculture

Climate change is affecting weather conditions and disturbing the normal farming period, so investment in irrigated agriculture at various strategic locations will assist in improving agricultural (crop) production, increasing farmers' income, maintaining the existing landscape and re-vegetate dry areas of soil during the period of low rainfall. The increase in agricultural production will boost the availability of food products, improve the social-wellbeing of the people, encourage youth empowerment in food processing, boost transportation and encourage earning of foreign reserve through agriculture.

5.5.2. Hydro-Electric Power Generation

Hydro-electric power generation is a clean energy, and if incorporated in the capital development of the river basin in strategic areas, it will provide Energy for industrial, commercial and domestic activities in the river basin. Dam projects would be enhanced, and water supply for commercial, industrial, domestic, and other uses would be provided for the benefit of the people. This will reduce fossil fuel burning, greenhouse gas emissions, and water, land, and air pollution, with all its attendant benefits.

5.5.3. Water Supply

Water Supply Services will be encouraged in the river basin by constructing dam projects. Investment in dam projects will enhance hydroelectric power generation, water supply services, and other benefits. The supply of potable drinking water will improve the health of inhabitants, create employment, and prevent waterborne diseases with adequate provision of water for domestic, agricultural, commercial, and industrial by maintaining the green vegetation in dry and adverse weather conditions.

5.5.4. Navigation/Water Transport

Navigation and marine transport are encouraged when the river channels are dredged. This will create employment in that sector and generate huge revenue for the South-Eastern River Basin Development Authority. When the rivers and water channels are properly dredged, drainage facilities in the riverine areas will be enhanced, flooding and overflowing of river banks will be reduced, and erosion hazards in the river basin will be reduced.

5.5.5. Drainage/Dredging

Drainage/Dredging of river channels will help boost navigation and water transport, immensely benefiting the region's inhabitants. This will also create employment through commercial and industrial activities.

5.5.6. Recreation/Tourism

Where natural and cultural heritage exists, rivers, waterfalls, or other exciting sites should be spotted and developed to generate revenue and create youth employment.

Maintenance of aquatic life will boost investment in fishery and other associated investments, providing sufficient food and social wellbeing for the people.

5.5.7. Flood Control

Construction of proper drainages and dredging of some water bodies will mitigate the danger of flooding the environment and distortion of business activities due to flooding. This will help to preserve our arable land from erosion and protect built-up areas from damage caused by flood-related hazards.

5.5.8. Plantation and Forestry

Investment in plantation and forestry will help restore or protect the ecosystem, create a healthy environment for the inhabitants, and improve environmental quality with other benefits.

5.5.9. Erosion Control

When proper drainages exist, gullies are converted to reservoirs. Plantation and forestry will assist in checking the hazard of erosion.

5.5.10. Reservoirs/Gullies

Areas where gullies exist could be converted to reservoirs. The water generated from the flood is stored and treated further for irrigation activities or water supply.

5.5.11. Gender Equality

When the inhabitants have a sense of belonging, they will engender equality while enjoying the benefits of healthy living. This will enhance active participation and efficiency in all areas of human activities.

5.5.12. Security

When the citizens are happy and busy, they think less of evil. Gainful employment, food security, financial security, irrigation agricultural products, flood and erosion control, water supply, and hydropower generation for commercial, industrial and domestic activities will help to reduce youth restiveness.

The protection of lives and properties will be enhanced. All these will help sustain the environment and maintain or militate against the effects of climate change.

6. Conclusion and Recommendation

There is much uncertainty in climate change projections and impacts on the ecosystem occasioned by human activities in the Environment. These actions have culminated in the natural causes of events that seriously threaten humans' existence.

- The robust and adaptive river basin management plans and measures should incorporate management strategies that deliver benefits irrespective of the climate condition.
- It is essential to have a clear understanding of the assumptions made and the uncertainties related to these assumptions when making projections and scenarios of climate change models for improving river basin management planning. This will help determine the individual or combination of measures most effectively achieving water management objectives to secure our uncertain future.
- The climate change status assessments in a river basin should incorporate human activities on the status of water bodies, impacts from anthropogenic pressures, and primary (direct) and secondary (indirect) impacts due to society's adaptation and mitigation activities to reduce risk for indirect or long-term drivers for the sustenance of basic infrastructural developments.
- Long-term consistent series of monitoring data for natural variation in climate-induced trends should be in place to establish or safeguard monitoring programmes that assist in benchmarking and tracking events as part of surveillance efforts. This is essential to detect and improve the prediction of impacts to improve the forecast of flood risks, water security and drought.
- Long term effectiveness and cost efficiency should incorporate sensitivity analysis under the changing climate conditions to yield beneficial outcomes irrespective of the eventual outcome of climate change.
- Full certainty in climate change predictions may not be achieved. However, adaptation to climate change will reduce the vulnerability of natural and human systems while advancing the policy from a reactive crisis management approach to a proactive risk management approach.
- The river basin managers should use the Bayesian and Game theory analysis to estimate expected monetary benefits for proper apportioning of available funds to various purposes and objectives to realize optimal benefits from their investment in the light of the global climate change scenario and projections.
- There should be measures to encourage the use of green and clean energy while implementing the purpose/objectives in a multipurpose/multi-objective South-Eastern River basin to reduce the impact of soil erosion, flood disasters, failure of reservoirs and dams, improve hydro-electric power generation, improve water supply, and check insecurity etc. that ravage our living environment.
- Implementing these recommendations will be a fertile ground for managing the river basin to generate revenue and financial benefits for the government, the community, and the social wellbeing of the inhabitants in the area.

The practical steps should be to execute the multipurpose project based on the result as prioritized by Bayesian and Game theories in phases. The area for further research would include how varying the allocation of resources can increase the revenue generated to support the green revolution at the river basin.

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