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Balancing Climate Change Crisis using Markovian Decision Model for Optimal Solution in Benin-Owena River Basin, Nigeria

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ABSTRACT
The work is aimed at balancing climate change crisis using Markove decision model for solution in Benin-Owen River Basins, Nigeria. The objectives of the study are: to develop a Markovian-Based Model that tackles climate change crisis in the Benin-Owena River Basin, Nigeria and to Evaluate the Net Benefits of Multi-Purpose Projects in the Benin-Owena River Basin, including Irrigated agriculture, Flood control measures, Water supply systems, Dredging and erosion management, Hydropower generation. The problems investigated are: climate change which had caused imbalance of ecosystems, affecting both nature and people such as rivers, lake, stream etc., non-continuity of previous awarded contract by the present management is a decision problem due to non application of logical models, the release of insufficient funds by the Federal Ministry of Water Resources to BORBDA is a decision problem, and the un-standardized method of funds allocation by the Federal Ministry of Water Resources to river basins is a decision problem due to lack of logical models. The methods of the study involved: dynamic programming models and a Bill of Engineering Measurement and Evaluation. The results of the Markovian models showed that, the optimal solutions from year 205 to 2035 for the Benin-Owena River Basin would not require maintenance (k*=1), the total expected revenues or return for the ten years of minimum utilization of the basin’s assets were; F1(1) = ₦7.69 trillion for irrigation , if the state of the project in year 1 to 2 is excellent, F1(2) = ₦7,74 trillion for plantation and forestry, if the state of the project in year 3 to 4 is good, F1(3) = ₦8.03 trillion for drainage/flood control, if the state of the project in year 4 to 5 is fair, F1(4) = ₦8.47 trillion for river dredging /tourism, if the state of the project in year 6 to 8 is , F1(5) = ₦9.57 trillion hydro-electric Generation, if the state of the project in year 9 to 10 is poor. The study concluded that, the tests for hypothesis confirm that the performance of the Benin-Owena River Basin (prototypes) versus the (models) was at 100% with high component interactions. The annual revenue generated from the Benin-Owena River Basin is approximately ₦41.56 Trillion. A cost-benefit analysis indicates that an initial investment of ₦146.65 Billion by the Federal Government over a five-year period would yield a profit of ₦99.1 Billion, based on the simulated Markovian decision theory model, assuming deduction of the investment from the generated revenue.

Keywords: Markove Chain, Climate Crisis, Optimal Solution, With Maintenance, Without Maintenance,

I. INTRODUCTION

The intensification of climate change, primarily driven by human-induced factors such as rapid and unplanned urbanization, accelerated industrialization, and the extensive utilization of fossil fuels, has significantly disrupted the historically stable hydrologic cycle. This disruption has led to increased global temperatures, ozone layer depletion, and associated extreme weather events, ultimately compromising ecosystem integrity, water resource availability, and environmental sustainability.

According to Ikhazuagbe (2022), Nigeria's River Basin Development Authorities are statutory organizations mandated to manage the nation's water resources, with a focus on optimizing agricultural productivity and rural development. Each authority is responsible for a designated geomorphological zone, with core objectives encompassing the promotion of irrigation-based agriculture, enforcement of water pollution control measures, and provision of technical support to farmers for enhanced food production and processing. The operational efficacy of these authorities is, however, influenced by Nigeria's prevailing political and economic climate.

The optimal utilization of a nation's water resources has a profound impact on national economic growth, achieved through the controlled transformation of natural watershed environments and infrastructure development. To attain economic efficiency in water resources development projects, it is essential to optimize economic benefits and costs. This is typically accomplished by minimizing cost functions, maximizing benefit functions, or employing a combination of both approaches. A direct benefit-cost index is a crucial metric for assessing economic efficiency.

In this context, economic optimization is undertaken using a continuous Markovian optimization model, building upon previous works that focused solely on linear programming and economic efficiency. This adjustment enables a standardized evaluation of the economic efficiency of multiple objectives, including federal economic redistribution, state economic redistribution, local economic redistribution, social wellbeing, and youth employment, within the context of the Benin-Owena River Basin's multi-purpose water resources planning and management. This approach aims to mitigate potential climate change-related crises and their impacts on future generations.

The benefits of water resources development projects are diverse and context-dependent, with varying determinants of economic benefits across different purposes and projects. For instance, irrigation agriculture benefits are influenced by factors such as increased crop yields, improved water availability, and enhanced food security, whereas water supply benefits are driven by domestic and industrial water availability, as well as improved public health. Similarly, hydro-electric power generation benefits are shaped by electricity output, energy security, and reduced greenhouse gas emissions, whereas drainage benefits are influenced by flood control, reduced erosion, and increased land usability. Dreging and tourism benefits, on the other hand, are driven by tourist visits, job creation, and local economic stimulation. A comprehensive understanding of these benefit determinants is essential for evaluating the economic efficiency and sustainability of water resources development projects, and for informing decision-making processes that balance competing objectives and priorities.

1.1 Statement of Research Problem

According to Ojiako (2001) and the U.S. Water Resources Council Special Task Force (1977 & 1970a & b), a country with substantial economic and water resource potential, such as Nigeria, cannot achieve optimal development and prosperity without harnessing the benefits of resource development and utilization.

In order to forestall a repetition of the challenges encountered by the River Basins Development Authority, a thorough review of the existing issues and the implications of climate change are essential, and solutions must be implemented expeditiously. The majority of these issues are decision-making dilemmas facing policymakers, specifically: (i) climate change which had caused imbalance of ecosystems, affecting both nature and people such as rivers, lake, stream etc., (ii) climate change which had caused large areas of land to be flooded with associated losses of agricultural land or gullies and displacements of communities, (iii) changing climate on reservoirs which led to a range of evaporation imbalance and socio-economic impacts, (iv) climate change which had caused depletion in hydroelectric power generation, reservoir water for hydropower, water supply, drought impact etc., (v) non-continuity of previous awarded contract by the present management is a decision problem due to non application of logical models, (vi) the release of insufficient funds by the Federal Ministry of Water Resources to BORBDA is a decision problem, and (vii) the un-standardized method of funds allocation by the Federal Ministry of Water Resources to river basins is a decision problem due to lack of logical models.

1.2 Aim and Objectives of the Study

The study is aimed at balancing climate crisis using Markovian decision model for optimal solution in Benin-Owena River Basin, Nigeria. The objectives of the study are : (i) to develop a Markovian-Based Model that tackles climate change crisis in the Benin-Owena River Basin, Nigeria (ii) to evaluate the Net Benefits of Multi-Purpose Projects in the Benin-Owena River Basin, including Irrigated agriculture, Flood control

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measures, Water supply systems, Dredging and erosion management, Hydropower generation.

II. METHODS

The research methodology involved dynamic programming models to optimize decision-making processes and evaluate the performance of the Benin-Owena River Basin. Questionnaires were developed and distributed to stakeholders, and data were collected. The Bill of Engineering Measurement and Evaluation was developed. The experiments evaluated the performance of the Benin- Owena River Basin as a technique of solving the problem of climate change crises (Prototype). This experiment was based on some behavior and actions of the Gardener / Farmer as the decision maker in terms of his application of Markovian Models in selecting the most suitable project among alternatives that would give highest yield or production according to Handy (2008) and Hiller & Lieberman (1995) respectively.

Thus, this action as the decision maker results in gains or losses depending on the state of the soil condition / nature or the system for the season / period. Therefore, it could be said that the method for productivity of the season is dependent on the soil condition: (very excellent, excellent, very good, good, very fair, fair, weak, very weak, poor, and very poor) as a scale of measurement. The state of the soil condition in a particular year helps the Gardener / Farmer in his action to apply or not to apply fertilizer in the next farming season.

Consequently, the above Gardener's / Farmer's example is an experimental model which was used to evaluate the performance of the prototype (River Basin Engineering Development Projects) in Planning and Management as a solution to the climate change crisis. The Farmer's / Gardener's example or the gardener's problem is a decision problem to either apply or not to apply fertilizer (to maintain or not to maintain) within the season. If the same conception of model is used to evaluate the performance of the maintenance of the River Basin sustainable projects in Edo and Ondo southern, region of Nigeria, that had suffered absence of inherited management experience, shortage of administrative and technical man power, lack of basic plan technical data, organizational inadequacies, financial constraints, etc., which led to flooding of Edo and Ondo, southern region, Nigeria, destruction of trees / forest, degradation of the environment, causing gullies all over the region.

From the foregoing, the application of the model to fertilize or not to fertilize on the system / prototype means to maintain or not maintain the system. Based on the literature reviewed, a nation with the economic and great water resources potentials as Nigeria cannot proffer solution to the climate change crisis without maintenance of sedimentation, (dredging) of the rivers / drainages, and the benefits of the full capacity utilization of the resources development.

Thus, maintenance of the river basins, will result in ecosystem balance generating an efficient economy with green energy project revolution like hydro-electric power generation, water supply, irrigated agriculture, tourism / recreation, drainages / dredging of rivers, flood / erosion control, plantation / forestry and reservoir / gullies prevention.

Table 2.1 shows the proposed summary Bill of Engineering Measurement and Evaluation (BEME) for capital projects in the Benin Owena Basin of Nigeria under various objectives. (With maintenance)

Development Project	**Objectives**					**Total Amount**
	Economic efficiency	Federal Economic Redistribution	State Econom ic redistrib ution	Social Well-being	Youth Employment	
Irrigated Agriculture	1.7	2.5	0.8	0.8	3.4	9.40 Billion
Plantation and Forestry:	2.3	3.4	1.2	1.2	4.5	12.60 Billion
Drainage/flood Control	0.03	0.05	25.8	25.8	0.07	51.75 Billion

River dredging /tourism	2.2	3.2	1.1	1.1	4.2	11.80 Billion
Hydro-electric Generation	8.4	12.6	4.2	4.2	16.8	46.20 Billion
Total Amount	14.63	21.75	33.10	33.10	28.97	131.75 Billion

Table 2.2 shows the proposed summary Bill of Engineering Measurement and Evaluation (BEME) for capital projects in the Benin Owena Basin of Nigeria under various objectives (Without maintenance)

Development Project	**Objectives**					**Total Amount**
	Economic efficiency	Federal Economic Redistribution	State Economic redistribution	Social Well-being	Youth Employment	
Irrigated Agriculture	1.9	2.8	0.9	0.9	3.8	10.30 Billion
Plantation and Forestry:	2.5	3.8	1.3	1.3	5.0	13.90
Drainage/flood Control	0.41	0.06	28.75	28.75	0.08	58.05 Billion
River dredging /tourism	2.4	3.5	1.2	1.2	4.7	13.00 Billion
Hydro-electric Generation	9.3	14.0	4.7	4.7	18.7	51.40 Billion
Total Amount	16.51	24.16	36.85	36.85	32.28	146.65 Billion

2.1 Finite-stage Method of the Markov Optimization Solutions for Maintenance and Without Maintenance Program of the Multi Projects of Benin-Owena River Basin Projects : Computation of $V^1{}_1$ and $V^2{}_1$, stage 1

(a) Let us evaluate a case of gross benefit in which the model of using the Gardener's problem of no fertilizer or maintenance application is (K=1) as in the computation of $V.^k{}_1$.

$V_1{}^1$ = (0.2 x 1.9) + (0.2x 2.8) + (0.25 x 0.9) + (0.25 x 0.9) + (0.1 x 3.8) = 1.77 Billion irrigated agriculture

$V_2{}^1$ = (0 x 2.5) + (0.30 x 3.8) + (0.25 x 1.3) + (0.15 x 1.3) + (0.3 x 5.0) = 3.16 Billion Plantation and forestry:

$V_3{}^1$ = (0 x 0.41) + (0 x 0.06) + (0.35 x 0.02) + (0.35 x 0.02) + (0.3 x 0.08) = 0.038 Billion Drainage/flood Control

$V_4{}^1$ = (0 x 2.4) + (0 x 3.5) + (0 x 1.2) + (0.6 x 1.2) + (0.4 x 4.7) = 2.6 Billion River dredging /tourism

$V_5{}^1$ = (0 x 9.3) + (0.x 14) + (0.4 x 7) + (0 x 4.7) + (1 x 18.7) = 18.7 Billion Hydro-electric generation

Therefore, if the Benin Owena River Basin Engineering Development Project is excellent, a single transition will yields 1.77B; if it is good, the yield is 3.16B; if it is fair, the yield is 0.038B; if it is weak, the yield is 2.6B; and if it is poor, the yield is 18 7B. In this method of the gardener's problem of without application of fertilizer, the decision problem is solved using the data summarized in the matrices given a horizon of 10 years only (N = 10) because the model developed has ten minimum number of stationary strategies.

(b) Let us similarly evaluate the case of net benefit in which the model uses the Gardener's problem of application of fertilizer / maintenance is (K=2) as computed below for $V.^k{}_1$.

$V_1{}^1$ = (0.25 x 1.7) + (0.15 x 2.5) + (0.2 x 0.8) + (0.15 x 0.8) + (0.25 x 3.4) = 1.93 Billion irrigated agriculture

$V_2{}^1$ = (0.3 x 2.3) + (0.15 x 3.4) + (0.15 x 1.2) + (0.2 x 1.2) + (0.2 x 4.5) = 2.52 Billion Plantation and forestry:

$V_3{}^1$ = (0. 15 x 0.03) + (0.25 x 0.05) + (0.3 x 0.01) + (0.18 x 0.01) + (0.12 x 0.07) = 0.030 Billion Drainage/flood control

$V_4{}^1$ = (0.3 x 2.2) + (0.25 x 3.2) + (0.15 x (-0.03) + (0.1 x 1.1) + (0.20 x 4.2) = 2.41 Billion River dredging /tourism

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V_5^1 = (0. 15 x 8.4) + (0.2 x 12.6) + (0.15 x 4.2) + (0.2 x 4.2) + (0.3 x 16.8) = 10.29 Billion Hydro-electric generation

Consequently, if the case of application of maintenance to the Benin Owena River Basin Engineering Development Project is excellent, a single transition will yields 1.93B; if it is good, the yield is 2.52B; if it is fair, the yield is 0.030B; if it is weak, the yield is 2.41B; and if it is poor, the yield is 10,29B. In this method of the gardener's problem of application of fertilize, the decision problem is solved using the data summarized in the matrices, given a horizon of 10 years only (N=10) because the model developed has also ten minimum number of stationary policies.

Table 2.3 shows the computation of V^1_1 and V^2_1, stage 9

$V_1^k + P_1^k F_{i0}^{(1)} + P_{i2}^k F_{10}^{(2)} + P_{i3}^k F_{10}^{(3)} P_{i4}^k F_{10}^{(4)} P_{i5}^k F_{10}^{(5)} P_{i6}^k F_{10}^{(6)} P_{i7}^k F_{10}^{(7)} P_{i8}^k F_{10}^{(8)} P_{i9}^k F_{10}^{(9)} P_{10}^k F_{i0}^{(10)}$				Optimal Solution
S/N	K =1	K = 2	K_9(i)	K *
1.	1.77+(0.2x1.77) + (0.2x3.16) + (0.25 x 0.04)+(0.25x2.6) + (0.1x18.7) = 5.29	1.93+(0.25x1.93)+(0.15x2.52) + (0.2x 0.03) + (0.15x2.41)+ (0.25x10.29) = 5.73	5.29	1
2.	3.16 + (0x1.77)+(0.3x3.16)+(0.25x0.04) +(0.15x2.6)+(0.3x18.7) = 10.12	2.52 + 0.3x1.93) +0.15x2.52)+(0.15x0.03) + (0.2x2.41)+(0.2x10.29) = 6.02	10.12	1
3.	0.04+(0x1.77)+(0x3.16)+0.35x0.04)+ (0.35x2.6)+0.3x18.7) = 6.57	0.03+(0.15x1.93)+0.25x2.52)+0.3x0.03)+ (0.18x2.41)+(0.12x10.29) = 2.63	6.57	1
4.	2.6+(0.x177)+(0x3.16)+(0.x0.04) +(0.6x2.6)+(0.4x18.7) = 11.64	2.41 + (0.3x1.93) +(0.25x2.52) + (0.15 x 0.03)+(0.1x2.41)+(0.2x10.29) =5.92	11.64	1
5.	18.7+(0x1.77)+(0x3.16)+(0x0.04) +(0x2.6)+(1x18.7) = 37.4	10.29+(0.15x1.93)+(0.2x2.52)+(0.15 x0.03)+(0.2x2.41)+(0.3x10.29)=14.66	37.4	1

Table 2.4 shows the computation of V^1_1 and V^2_1, stage 8

$V_1^K+P^K_{11}F_9^{(1)}$ + $P_{12}KF_9^{(2)}$ + $P_{13}KF_9^{(3)}$ + $P_{14}F_9^{(4)}$ + $P_{15}F_9^{(5)}$ + $P_{16}F_9^{(6)}$ + $P_{17}F_9^{(9)}$ + P_{16} $F_9^{(8)}$ + $P_{19}F_9^{(9)}$ + $_{10}F_{10}^{(10)}$				Optimal Solution
S/N	K =1	K = 2	F_8(i)	K *
1.	5.29 +(0.2x5.29)+(0.2x10.12) + (0.25 x 6.567)+(0.25x11.64)+(0.1x37.4) = 16.66	5.73+(0.25x5.29)x(0.15x10.29)+ (0.2x 6.57)+0.15x11.64)+(0.25x37.4) = 21.01	16.66	1
2.	10.12+(0x5.29)+(0.3x10.12)+(0.25x6.57)+(0.15x11.64)+(0.3x37.4) = 27.76	6.02+)0.3x5.29)(+(0.15x10.12)+ (0.15x6.57)+(0.2x11.64)+(0.2x37.4) = 20.15	27.76	1
3.	6.57+(0x5.29)+(09x10.12)+(0.35x6.57) +(0.35x1.64)+(0.3x37.4) = 24.16	2.63+(0.15x5.29)+(0.25x10.12)+ (0.30x6.57)+(0.18x11.64)+(0.12 x37.4) = 14.51	24.16	1
4.	11.64+(0x5.29)+(0x10.12)+(0x6.57)+(0.6x11.64)+(0.4x37.4) = 33.58	5.92+(0.3x5.29)+(0.25x10.12)+(0.15x6.57)+(0.1x11.64)+(0.2x37.4) = 19.67	33.58	1
5.	37.4+(0x5.29)+(0x10.12)+(0x6.57)+(0x 11.64)+(1x37.4) = 74.8	14.66+(0.15x5.29)+(0.2x10.12)+ (0.15x6.57)+(0.2x11.64)+(0.3x37.4) = 32.01	74.8	1

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Table 2.5 shows the computation of V^1_1 and V^2_1, stage 7

$V_1^k + P_1^k F_8^{(1)} + P_{12}^k F_8^{(2)} + P_{13}^k F_8^{(3)} P_{14}^k F_8^{(4)} P_{15}^k F_8^{(5)} P_{16}^k F_8^{(6)} P_{17}^k F_8^{(7)} P_{18}^k F_8^{(8)} P_{19}^k F_8^{(9)} P_{10}^k F_8^{(10)}$				Optional Solution
S/N	K =1	K = 2	F_7(i)	K *
1.	16.66+(0.2x16.66)+(0.2x27.76)+(0.25x24.16)+(0.25x33.58)+0.1x74.8) = 47.46	21.01+(0.25x16.16)+(0.15x27.76)+(0.2x24.16)+0.15X33.58)+(0.25x74.8) = 57.91	47.46	1
2.	27.76+(0x16.16)+0.3x27.76)+0.25x 24.16)+(0.15X33.58)+(0.3x74.8) = 69.61	20.15+(0.3x16.66)+(0.15x27.76)+(0.15x24.16)+(0.2x33.58)+(0.2x74.8) = 99.59	69.61	1
3.	24.16+(0x16.66)+(0.2x7.76)+(0.35x 24.16)+(0.35x33.58)+(0.3x74.8) = 66.81	14.51+(9,15x16,66)+(0.25x27.76)+(09.3x24.16)+(0.18x33.58)+(0./12x74.8) = 46.22	66.81	1
4.	33.58+(0x16.66)+(0x27.76)+(09x24.16)+(0.6x33.58)+0.4x74.80) = 83.65	19.67+(0.3x16.66)+(0.256x27.76)+(0.15x24.16)+(0.1x33.58)+(0.2x74.8) = 40.15	83.65	1
5.	74.8+(0x16.66)+(0x27.76)+(0x24.16)+(0.33.85)+(1x74.8) = 149.60	32.10+(0.15x16.66)+(0.2x27.76)+(0.15x24.16)+(0.2x33.58)+(0.3x74.8) = 72.84	149.60	1

Table 2.6 shows the computation of V^1_1 and V^2_1, stage 6

$V_1^k + P_1^k F_7^{(1)} + P_{12}^k F_7^{(2)} + P_{13}^k F_7^{(3)} P_{14}^k F_7^{(4)} P_{15}^k F_7^{(5)} P_{16}^k F_7^{(6)} P_{17}^k F_7^{(7)} P_{18}^k F_7^{(8)} P_{19}^k F_7^{(9)} P_{10}^k F_7^{(10)}$				Optional Solution
S/N	K =1	K = 2	F_6(i)	K *
1.	47.46+(0.2x47.46)+(0.2x69.61) +(0.25x66.81)+(0.25x83.65)+(0.1x149.60)= 123.45	57.91+(0.25x47.46)+(0.15x67.46) +(0.2x66.81)+(0.15x83.65)+(0.25x 149.6) = 143.20	123.45	1
2.	69.61+(0x47.46)+(0.3x69.61)+(0.25x66.81)+(0.15x83.65)+(0.3 x149.60) = 164.62	99.59+(0.3x47.46)+(0.15x69.61)+(0.15x66.81)+(0.2x83.65)+(0.2x149.60)=180.94	164.62	1
3.	66.81+(0x47.46)+(0x69.61)+(0.35x 66.81)+(0.35x83.65)+(0.3x149.6)=164.35	46.22+(0.15x47.46)+(0.25x69.61) +(0.3x66.81)+(0.18x83.65)+(0.12x 149.6) = 123.798	164.34	1
4.	83.65+(0x47.46)+(0x69.61)+(0x66.81)+ (0.6x83.65)+(0.4x149.6) =193.68	40.15+)0.3x47.46)+(0.25x69.61)+(0.15x66.81)+(0.1x83.65)+(0.2x149.6) = 120.10	193.68	1
5.	149.60+(0x47.46)+(0x69.61)+(0x66.81)+(0x83.65)+(1x149.60) = 299.20	72.84x (0.15x47.46) + (0.2x69.61) + (0.15x66.81)+0.2x83.65)+(0.3x149.60) = 306.42.	299.20	1

Table 2.7 shows the computation of V^1_1 and V^2_1, stage 5

$V_1^k + P_1^k F_6^{(1)} + P_{12}^k F_6^{(2)} + P_{13}^k F_6^{(3)} P_{14}^k F_6^{(4)} P_{15}^k F_6^{(5)} P_{16}^k F_6^{(6)} P_{17}^k F_6^{(7)} P_{18}^k F_6^{(8)} P_{19}^k F_6^{(9)} P_{10}^k F_6^{(10)}$				Optional Solution
S/N	K =1	K = 2	F_5(i)	K *
1.	123.45+ (0.2 x 123.45) + (0.2x 164.62) + (0.25x164.35) + (0.25x193.68)+(0.1x299.20) = 300.49	143.20+(0.25x123.45)+(0.15x164.62) + (0.2x164.35) +(0.15x193.68) + (0.25x299.20) = 335.48	300.49	1
2.	164.62+(0x123.45)+(0.3x164.62)+(0.25x164.35)	180.94+(0.3x123.45)+(0.15x164.62)+	373.91	1

	+(0.15x193.68) + (0.3x299.20) = 373.91	(0.15x164.35)+(0.2x193.68)+(0.2x 299.20) = 365.90		
3.	164.35+(0x123.45)+(0x164.62) +(0.35x164.35)+(0.35x193.68) +(0.3x299.20) = 379.42	123.79+(0.15x123.45)+(0.25x164. 62)+ (0.3x164.35)+(0.18 x 193.68) + (0.12x299.20) = 303.53	379.42	1
4.	193.68+(0x123.45)+(0x164)+(0 x164.62)+(0.6x193.68)+(0.4x2 99.20) = 429.57	120.10 +(0.3x123.45) +(0.25x164.62) +(0.15x164.35)+(0.1x193.68)+(0.2 x299.20) = 302.15	429.57	1
5.	299.20+(0X123.45)+(0x164.62)+ (0x164.35)+(0x193.68)+(1x299 .20) =598.40	306.42+(0.15x123.45)+(0.2x164.6 2)+ (0.15x164.35)+(0.2x193.68)+(0.3x 299.20) = 511.01	598.40	1

Table 2.8 shows the computation of V^1_1 and V^2_1, stage 4

$V_i^k + P_1^k F_5^{(1)} + P_{12}^k F_5^{(2)} + P_{13}^k F_5^{(3)} P_{14}^k F_5^{(4)} P_{15}^k F_5^{(5)} P_{16}^k F_5^{(6)} P_{17}^k F_5^{(7)} P_{18}^k F_5^{(8)} P_{19}^k F_5^{(9)} P_{10}^k F_5^{(10)}$				Optional Solution
S/N	K =1	K = 2	F_4(i)	K *
1.	300.49+(0.2x300.49)+(0.2x373.9 1)+(0.2x379.42)+(0.25x429.57)+(0.1x598.40) =678.49	335.48+(0.25x300.49)+(0.15x373. 91)+(0.2x379.42)+(0.15x429.57)+(0.25x594.4)=756.61	67849	1
2.	373.91+(0x300.49)+(0.3x373.91) +(0.25x379.42)+(0.15x429.57)+(0.3x598.40) = 824.90	365.90+(0.3x300.49)+(0.15x373.9 1)+ (0.15x379.42)+(0.2c429.57)+(0.2x 598.40) = 774.64	824.90	1
3.	379.42(0x300.49)+(0x373.91+(0. 35x379.42)+(0.35x429.57)+(0.3x 598.40) = 842.09	303.53+(0.15x300.49)+(0.25x373. 91) +(0.3x379.42)+(0.18x429.57)+(0.1 2x598.40) = 705.04	842.09	1
4.	429.57+(0x300.49)+(0x373.91)+(0x379.42)+(0.6x429.57)+(0.4x59 8.40) = 926.67	306.42+(0.15x300.49)+(0.2x373.9 1)+ (0.15x379.42)+(0.2x4.29.57)+(0.3 x598.40) = 748.62	926.67	1
5.	598.40+(0x300.49)+(0x373.91)+(0x379.42)+(0x429.57)+(1x598.40) = 1,196.80	511.01+(0.15x300.49)+(0.2x373.9 1)+(0.15x379.42) +(0.2x429.57)+ (0.3x 598.40) = 9.53.21	1,196.8	1

Table 2.9 shows the computation of V^1_1 and V^2_1, stage 3

$V_i^k + P_1^k F_4^{(1)} + P_{12}^k F_4^{(2)} + P_{13}^k F_4^{(3)} P_{14}^k F_4^{(4)} P_{15}^k F_4^{(5)} P_{16}^k F_4^{(6)} P_{17}^k F_4^{(7)} P_{18}^k F_4^{(8)} P_{19}^k F_4^{(9)} P_{10}^k F_4^{(10)}$				Optional Solution
S/N	K =1	K = 2	F_3(i)	K *
1.	678.49 +(0.2x678.49) +(0.2x824.90) + 0.2x842.09)+(0.25x926.67)+0.1x1, 196.80) = 1,363.24	756.61+(0.25x678.49)+(0.15x824 .90)+ (0.2x842.09)+(0.15x926.67)+(0.2 5x1,196.80) =1,656.59	1,363.24	1
2.	824.90 +(0x678.49)+(0.3x824.90) + (0.25x842.09)+(0.15x926.67)+(0.3 x1.196.80) = 1,780.93	774.64+(0.3x678.49)+(0.15x824. 90)+ (0.15x842.09) +(0.2x926.67)+ (0.2x1,196.80) = 1,624,06	1,780.93	1
3.	842.09+(0x678.49)+(0x824.90)+(0 .35x842.09)+(0.35x926.67)+0.3x1, 196.80) =1,820.20	705.04+(0.15x678.489)+(0.25x82 4.90)+(0.3x842.09)+(0.18x926.67)+(0.12x1,196.80) = 1,576.08	1,820.20	1
4.	926.67+(0.678.49)+(0x824.90)+(0 x842.09)+(0.6x926.67)+(0.4x1,196	748.62+(0.15x678.49)+(0.2x824. 90)+	1,961.39	1

	.80) = 1,961.39	(0.15x842.09)+(0.2x926.67)+(0.3x1,196.80) = 1,686.06		
5.	1,196.80+(0x678.49)+(0x824.90)+(0x842.09)+(0x926.67)+(1x1,196.80) =2,393.60	953.21+(0.15x678.49)+(0.2x824.90)+(0.15x842.09+(0.2x926.67)+(0.3x1,196.80)= 1,890.65	2,393.60	1

Table 2.11 shows the computation of V^1_1 and V^2_1, stage 2

$V_1^k + P_1^k F_3^{(1)} + P_{12}^k F_3^{(2)} + P_{13}^k F_3^{(3)} P_{14}^k F_3^{(4)} P_{15}^k F_3^{(5)} P_{16}^k F_3^{(6)} P_{17}^k F_3^{(7)} P_{18}^k F_3^{(8)} P_{19}^k F_3^{(9)} P_{10}^k F_3^{(10)}$				Optional Solution
S/N	K =1	K = 2	$F_2(i)$	K *
1.	1,363.24+(0.2x1,363.24)+(0.2x1,780.93)+(0.2x1,820.20)+(0.25x1,961.39)+ (0.1x2,393.60) = 3,885.82	1.656.59+(0.25x1,363.24)+(0.15x1,780.93)+(0.2x21,820.20)+(0.15x1,961.39) +(0.25x2,393.60) = 3,521.19	3,885.82	1
2.	1,780.93+(0x1363.24)+(0.3x1780.93)+(0.25x1820.20)+(0.15x1961.39)+(0.3x2393.6) = 3,782.55	1624.6+(0.3x1363.24)+(0.15x1780.93)+(0.15x1820.20)+(0.2x1961.39)+(0.2x2393.60) = 3,444.20	3,782.55	1
3.	1820.20+(0x1363.24+(0x1780.93)+(0.35x1820.2)+(0.35x1961.39)+(0.3x2393.6) = 3,861.84	1576.08(0.15x1363.24)+(0.25x1780.93)+(0.3x1820.20)+(0.18x1961.39)+(0.12x2393.60) = 34,12.14	3,861.84	1
4.	1961.39+(0x1363.24)+(0x1780.93)+(0x1820.2)+(0.6x1961.39)+(0.4x2393.60) = 4,095.67	1686.06x(0.15x1363.24)+(0.2x1780.93)+(0.15x18290.20)+(0.2x1961.39)+ (0.3x2393.60) = 3,630.12	4,095,67	1
5.	2393.60+(0x1363.24)+(0x1780.93)+(0x1820.20)+(0x1961.39)+(0x1961.39)+(1x2393.60) = 4,787.20	1890.65+(0.15x1363.24)+(0.2x1780.93)+(0.15x1820.20)+(0.2x1961.39)+(0.3x2,393.60) = 3,834.71	4,787.20	1

Table 2.11 shows the computation of V^1_1 and V^2_1, stage 1

$V_1^k + P_1^k F_1^{(1)} + P_{12}^k F_1^{(2)} + P_{13}^k F_1^{(3)} P_{14}^k F_1^{(4)} P_{15}^k F_1^{(5)} P_{16}^k F_1^{(6)} P_{17}^k F_1^{(7)} P_{18}^k F_1^{(8)} P_{19}^k F_1^{(9)} P_{10}^k F_1^{(10)}$				Optional Solution
S/N	K =1	K = 2	$F_1(i)$	K *
1.	3,885.82+(0.2x3885.82)+(0.2x3,782.55)+0.2x3,861.84)+0.25x4095.67)+0.1x4787.20) = 7,694.50	3521.19+(0.25x3885.82)+(0.15x3782.55)+(0.2x3861.84)+(0.15x4095.67)+(0.25x4,787.20) = 7,643.55	7,694.50	1
2.	3782.55+(0x3885.82)+(90.3x3782.55)+0.25x3861.84)+(0.15x4095.67)+ (0.3x4787.20) = 7,740.19	3444.20+()0.3x3885.82)+(0.15x3782.55)+(0.15x3861.84)+(0.2x4095.67)+ (0.2x4787.20) = 7,533.18	7,740.19	1
3.	3861.84+(0.x3885.82)+(0x3782.55)+(0.35x4095.67)+(0.3x4787.20) = 8,083.13	3412.14+(0.15x3885.82)+(0.25x3782.55)+(0.3x4861.84)+(0.18x4095.67)+ (0.12x4787.20) = 7,410.89	8,084.13	1
4.	4095.67+(0x3885.82)+(0x3782.55)+(0x3861.84)+(0.6x4095.67)+(0.4x4.787.20) = 8,467.95	3630.12+(0.15x3885.82)+(0.2x3782.55)+(0.15x3861.84)+(0.2x4095.67)+ (0.3x4787.20) = 7,804.07	8,467.95	1
5.	4787.20+(0x3885.82+(0x3782	3834.71+(0.15x3885.82)+(0.2x378	9,574.40	1

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	.55)+ (0x3861.84)+(0x4095.67)+(1x 4787.20) = 9.574.40	2.55)+(0.15x3861.84)+(0.2x4095.6 7)+ (0.3x4787.20) = 8,008.66		

III. RESULTS AND DISCUSSION

3.1 Presentation of Results of the Markovian without Maintenance and with Maintenance Program

Discussion and interpretation of Markovia results without maintenance program which shows the performance results of the Markovian experimental model as follows: (i) Markovian model makes a total profit returns on investment of ₦38.47 Trillion annually after ten years, minimum capacity utilization, and (ii) Hydro-electric generation make the highest total profit returns on investment of ₦8.09 Trillion annually followed by, River dredging /tourism - ₦7.80 Trillion, Irrigated Agriculture - ₦7. 64 Trillion, Plantation and forestry - ₦7.53 Trillion, and Drainage for flood Control -₦7.41 Trillion.

Markovia optimization model results with maintenance program on the other hand makes expected returns as follows: (i) Markovian model makes a total profit returns on investment of ₦41.56 Trillion annually after ten years, minimum capacity utilization, and (ii) Hydro-electric generation make the highest total profit returns on investment of ₦9.574Trillion annually followed by, River dredging /tourism - ₦8.467 Trillion, Drainage/flood Control - ₦8.467 Trillion, Plantation and forestry - ₦7.740 Trillion, and Irrigated Agriculture - ₦7. 694 Trillion. Since the Markovian decision model is based on logical allocation of water resources projects.

3.1.2 Discussion of the Sustainable Projects for Benin Owena River Basin as a Solution that Necessitated the Following Climate Change Policy

Based on the data analysis and calculations, utilizing Markovian decision theories, optimal solutions have been formulated for the Benin Owena River basin, aimed at addressing the climate change challenges identified in the study's objectives.

The implementation of irrigated agriculture in the Owena River Basin is anticipated to yield numerous benefits, including enhanced economic sustainability through improved agricultural productivity, balanced landscapes, and soil conservation. It is recommended that irrigated agriculture be adopted in designated areas of Edo and Ondo states, as it is poised to address food scarcity, provide employment opportunities for youth, facilitate the preservation and transportation of agricultural products, and generate foreign exchange earnings through the sale of produce. Furthermore, the integration of wind-powered irrigation systems is expected to mitigate pollution and contribute to a more sustainable agricultural practice.

The establishment of plantations and forestry initiatives is crucial for maintaining ecological balance and mitigating climate change. Through photosynthesis, trees and plants absorb carbon dioxide, a greenhouse gas, and produce oxygen, thereby contributing to improved air quality. Strategic locations such as Iguobazuwa, Igbokoda, Sabongida-Ora, Owo, Ifon, and Afuze are identified as suitable areas for the cultivation of palm, plantains, banana, mango, orange, and coconut, among other species. This will help to restore our climate, provide jobs and security through employment.

The construction of adequate drainage systems in Irrua, Ifon, and Auchi, coupled with the dredging of water bodies, will facilitate the efficient management of stormwater runoff, thereby mitigating the risk of flooding and preserving arable land and property, ultimately contributing to climate regulation.

The implementation of effective flood control measures, including the dredging of rivers and construction of adequate drainage systems in Irrua, Ifon, and Auchi, will mitigate the impact of rainfall-induced flooding, thereby safeguarding arable land and property, and contributing to climate stability. Furthermore, the development of recreational and tourism infrastructure in areas such as Abudu, Inugbo, Oredo, Ore, and Iguobazuwa, is expected to generate revenue, stimulate economic growth, and create employment opportunities, thereby addressing socio-economic challenges and promoting regional development.

Hydro-electric power generation: The turbine in complete revolution through water, as a clean source of energy has no form of pollution to the air like power plants that burn fossil fuel. Hydroelectric power is a domestic source of energy allowing each state of Edo and Ondo to produce their own energy without being dependent on fuel as practiced before in all the areas of the states. With power (electricity) generated, this will eliminate the use of fossil fuel that pollute the air, provide employments for the youth, increase foreign reserve and reduce the import of fuel, reduce insecurity, mass movement to urban areas and this will help to reverse the climate change in the region.

Table 2.12 shows the Comparison of Results of the Markovian Performance on Experimental Models of without Maintenance and with Maintenance Program

S/N	Without Maintenance	With Maintenance
1	F1 = ₦7. 694 Trillion, if the state of the project in year 1 to 2 is excellent	₦7.64 Trillion Irrigation
2	F1 = ₦7.740 Trillion, if the state of the project in year 3 to 4 is good	₦7.53 Trillion Plantation and forestry
3	F1 = ₦8.083 Trillion, if the state of the project in year 5 to 6 is fair	₦7.41 Trillion Drainage/ flood control
4	F1= ₦8.467 Trillion, if the state of the project in year 7 to 8 is weak	₦7.80 Trillion River dredging /tourism
5	F1= ₦9.574 Trillion, if the state of the project in year 9 to 10 is poor	₦8.09 Trillion Hydro-electric generation

IV. CONCLUSION

The work concludes that: (i) The optimal solutions in Markovian decision theory (without Maintenance), show that from year 2025 to 2035, the Benin Owena River basin in Edo and Ondo states of Nigeria will not require maintenance (k*=1), and (ii) The total expected annually revenue or return for ten years, minimum capacity utilization of the basin's assets are: F1 (1) = ₦7. 694 Trillion, if the state of the project in year 1 to 2 is excellent, F1 (2) = ₦7.740 Trillion, if the state of the project in year 3 to 4 is good, F1 (3) = ₦8.083 Trillion, if the state of the project in year 5 to 6 is fair, F1 (4) = ₦8.467 Trillion, if the state of the project in year 7 to 8 is weak, F1 (5) = ₦9.574 Trillion, if the state of the project in year 9 to 10 is poor.

A comparative analysis with the Markovian Decision Theory (with Maintenance) reveals that, from 2025 to 2030, the Benin Owena River basin in Edo and Ondo states, Nigeria, is projected to require maintenance and yield the following annual revenue streams: Irrigated Agriculture: ₦7.64 Trillion, Plantation and Forestry: ₦7.53 Trillion, Drainage/Flood Control: ₦7.41 Trillion, River Dredging/Tourism: ₦7.80 Trillion, Hydro-electric Generation: ₦8.09 Trillion

The projected annual revenue generated from the Benin-Owena River basin is approximately ₦41.56 Trillion. A cost-benefit analysis indicates that an initial investment of ₦146.65 Billion by the Federal Government over a five-year period would yield a profit of ₦99.1 Billion, based on the simulated Markovian decision theory model, assuming deduction of the investment from the generated revenue.

It is therefore clear that simulation modeling in Markovian decision theory in assessing the real-life performance of a system can be effectively applied in: optimum policy decision making, maintenance programming, allocation, conjunctively managed competitive Benin-Owena Basin, sharing of new expansion fund and logical cost sharing in multi-purpose / multi-objective River basin Engineering development.

The experimental results confirm that the performance of the Benin-Owena basin in Edo and Ondo states, Nigeria, exceeded theoretical expectations, exhibiting high component interaction. The application of regression analysis, specifically the Pearson product moment correlation coefficient (r), yielded a value of r = 1.0, indicating that the basin's assets operated at optimal levels, achieving 100% performance efficiency.

Therefore, with the project layout plan, the Authority will not only be released from bankruptcy, but will give more employment twice their present staff strength and also pay their Creditors and Contractors with enough foreign reserves. This research work, has provided solutions to the problems and consideration of multi-objectivity involved such as: economic efficiency, federal, regional, state, local economic redistribution, social well-being of the people, youth employment, under worst possible conditions involved in the following developments: Irrigation, Plantation / Forestry, Drainage/Flood Control, River Dredging /Tourism and Hydro-electric Generation. The problems of imbalanced water cycle and ecosystem have been solved with the proposed project/ layout plan which improves the environment with new sources of green energy technologies the restoration of climate change.

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