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Evaluation of Old Oyo National Park efficiency using DEA Approach

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Abstract: Measuring the efficiency of a national park is difficult due to, among other factors, the heterogeneity of resources supplied (e.g., budget, staffs) and outcomes expected (e.g., income, visitors' flow). While this is an issue in protected area management, it has been approached successfully in other fields by using data envelopment analysis (DEA). DEA has a number of advantages over other techniques as it simultaneously uses multiple heterogeneous inputs and outputs to determine which projects are performing most efficiently, referred to as being at the efficiency frontier, when compared to others in the data set. This study therefore uses DEA for the evaluation of management efficiency in Old Oyo National Park for the period of 2001-2015. The results showed that the park was efficient for 11 and 13 years, respectively, in terms of its overall technical and pure technical efficiency with a mean scale efficiency of 97%. Also, the park operated at 80% of its productive scale size. These results, and the use of DEA, highlight both the success of using this technique in helping determine protected area efficiency and those factors to consider while allocating resources for new projects at the park.

Keywords: national park, efficiency, resource allocation, protected area management

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1. Introduction

The concept of a 'natural park' has undergone several successive transformations, tracing back from the first meetings in Paris (1902) up to Rio de Janeiro in 1992, when a new interpretation emerged (Bosetti and Locatelli, 2006). The consensus at the meeting was that natural parks should be government-managed territories, where development and preservation forces are kept in balance. Management of these parks are not only to be concerned with environmental issues, but more broadly with the socio-economic features of the territory (Sanchez and Croal, 2012). This implies a long-term involvement and sustainable development of human activities within protected areas (PAs), thus, proving to be a win-win strategy (Bosetti and Locatelli, 2006). Sustainable development entails that economic growth must not deplete irreplaceable natural resources, must preserve the ecological systems and should help to reduce social inequalities worldwide (De Simone and Popoff, 2000).

With this new concept of management, effective park management involves the dynamic assessment of environmental quality indicators as well as the sustainability level of management activities, thus increasing the need for comprehensive indicators (Bosetti and Locatelli, 2006). Qualitative and quantitative indicators are needed to support the decision-maker in comparing different realities, evaluating the environmental and economic performance of its management's policies, and in trying to forecast the effectiveness of potential changes in management strategies (Bosetti and Locatelli, 2006).

With the prevailing economic scenarios in Nigeria, the parks are facing fierce competition for land, especially from the rural communities, leading to the loss of biodiversity and threatened ecosystem (Jacob *et al.*, 2015a, b; Jacob and Nelson, 2015). Also, the need for urbanization, increasing population, all forms of habitat change, over-exploitation, pollution, invasive alien species and climate change has also intensified the competition (Jacob *et al.*, 2013; Jacob and Ogogo, 2013; Ogogo *et al.*, 2010). As a result of intense competition, the proportion of the country's landmass and biodiversity under conservation is declining steadily. To reverse this situation, the country collaborated with international agencies and institutions such as: the Secretariat of the Convention on Biological Diversity (CBD), Global Environment Facility (GEF) and United Nations Environment Programme (UNEP) to revise its National Biodiversity Strategy and Action Plan (NBSAP) and ensure its implementation.

However, the success of implementing the plan and meeting the aspirations of the all stakeholders' hinges upon how efficiently the protected area managers can utilize their human and financial resources to deliver the expected outcome. Against this background, it has become pertinent to measure the extent of relative (in)efficiency of individual parks and to explore the areas for bringing an improvement in their efficiency. Furthermore, it is important to unearth whether the observed inefficiency in park is due mainly to managerial incapability or inappropriate choices. This study therefore measures the extent of technical, pure technical, and scale efficiencies of Old Oyo National Park, using data envelopment analysis (DEA) methodology to ascertain its level of efficiency. Data Envelopment Analysis (DEA) is considered as a useful approach because it is an extremely flexible and effective methodology, which provides an indicator of the relative efficiency for each different decision making unit analyzed, such as national park management processes, where efficiency is a measure of different features related to the environment as well as to the economic or social impacts of the protected area (Bosetti and Locatelli, 2006). This paper presents and discusses its application in the evaluation of the management efficiency of Old Oyo National Park, Nigeria.

2. Materials and methods

2.1. Models

A number of different approaches have been used to model park processes with the aim of obtaining a different aspect of efficiency. The most important approach is the production approach (Bosetti and Locatelli, 2006). Under the production approach, the parks are viewed as institutions making use of various labor and capital resources to provide different products and services to visitors. Hence, the resources being consumed, such as labor and operating cost are deemed as inputs while the products and the services such as ecotourism, research opportunities and park fees are regarded as outputs of the parks. This paper uses the production approach as its operational efficiency model. The model examines how well different variables combine their resources to support the largest amount of possible services.

2.2. Variables

The variables used in the study were obtained from Old Oyo National Park annual report from 2001–2015. The initial data contained 10 variables, however, after the variables were defined, some variables were removed due to lack of necessary information. Thus, the efficiency analysis was carried out with 8 variables containing all the required information. The choice of variables required the identification of elements considered in the literature and the information available in the National Park. Thus, based on the reviewed literature and the information available, the input and output variables were selected. Table 1 summarizes the variables used in the study.

Table 1: Variables used to elaborate the model

Variable	Identification	Meaning
Staff	Input	Labor, people who provide the services in the park
Operating expenses	Input	Expenses with park operations
Offence	Input	Effectiveness of law enforcement in the park
staff training	Input	Empowering *employees* with requisite skills
income	Output	Revenue obtained from providing services in the park
visitors	Output	Indicator of attractiveness of the park to the public
internship	Output	Suitability of the park to serve as hands-on experience to early career seekers
research	Output	Conducive nature of the park for researches to be successfully conducted

Source: Elaborated by the authors.

Four variables were selected as inputs: number of staff, operating expenses (budget), number of offences and number of staff trained. Number of staff represents labor, the human resources providing services in the park (Saha and Ravisankar, 2000; Sathye, 2003; Macedo and Barbosa, 2009; Cava *et al*., 2016). Operating expenses represent the cost of the park's operations (Sathye, 2003; Liu, 2009; Wanke *et al*., 2015). The third input offences represent the effectiveness of law enforcement in the park (Challender and MacMillan, 2014; Tranquilli *et al*., 2014; Challender *et al*., 2015) and number of staff trained represent the number of staff that have been empowered with requisite skills to function effectively in the park (Ginsberg, 1997; Apospori *et al.*, 2008).

The outputs were also represented by four variables: income representing the revenue obtained from services the park provided (Ayodele, 2002; Meduna *et al*, 2005; Lindsey et al, 2007; Adejumo *et al*., 2014), the number of visitors represent the attractiveness of the park to the public (Bhandari, 1999; Balmford *et al*., 2009), internship represent the number of interns who successfully completed their internship and had hand-on experience in the park (Jackson and Wirt, 1996; Sovilla, 1998; Jackson, 2009; Renz, 2015) and the amount of research represents the conducive nature of the park for research to carry out their field work. Characteristics of the input and output variables are shown in *Table 2*.

Table 2: Demographics of the input and output variables

Variable	Budget	Staff strength	Offence	Staff training	Income	Visitors	Internship	Research
Mean	119876868.7	229.80	96.53	59.53	3938951	2748.13	34.47	60.27
Standard Error	19104717.45	9.41	8.72	13.21	730220.5	709.8542	8.08	6.49
Minimum	42072788	184	38	1	238825.1	281	1	12
Maximum	294381845.8	290	158	153	8291390	9376	121	91

Source: Elaborated by the authors.

2.3. Data Envelopment Analysis (DEA)

DEA is a non-parametric method that has been widely used to assess relative efficiency (Fethi and Pasiouras, 2010). It is a mathematical programming technique originally developed by Charnes *et al*. (1978), and is used to evaluate the relative efficiency of a number of homogeneous units called Decision Making Units (DMUs). These units perform similar activities in order to make the comparisons (Périco *et al.*, 2008). According to Thanassoulis (2003), the DEA technique was developed to compare the relative efficiency of units (DMUs) that perform similar functions with regard to resources used and outputs produced through the ratio of weighted outputs to weighted inputs of each DMU. DMUs are compared with each other by constituting linear programming model (LP). As a nonparametric test, it does not require statistical assumptions. Therefore, there is no functional form for the frontier, such as a linear or exponential one. It is constructed out of the data (Macoris *et al.*, 2015). The DEA technique compares DMUs and presents a score for each one. DMUs that have a score of 1 are efficient, while those with a score lower than 1 are inefficient. This score is determined by analyzing inputs and outputs. The inputs and outputs are determined by the manager or researcher, but what influences their choice is the objective of the analysis (Cava *et al*., 2016).

DEA is primarily used to improve planning and controlling of the activities of public institutions (Charnes *et al*., 1978). In addition, it is also used to measure the relative efficiency in many areas and institutions such as hospitals, schools, factories, government business enterprises, service industry, parks, etc. (Soysal-Kurt, 2017). This paper discusses one of the areas DEA is being used in protected area management.

DEA models are divided into two categories according to scale and orientation (Figure 1) namely; constant return to scale (CRS) and variable return to scale (VRS). CRS assumes that there is no substantial relationship between scale and efficiency of the DMU. If inputs change in a proportion, outputs change in that proportion. In VRS, there are increasing, decreasing and constant returns to scale for production process (Soysal-Kurt, 2017). According to the orientation, DEA differs depending on input-oriented, output-oriented and non-oriented models. In input-oriented models, it is aimed at minimizing the number of inputs to produce predetermined outputs. In output-oriented models, it is aimed to produce maximum output using predetermined inputs. Overall technical efficiency or CCR (Charnes, Cooper and Rhodes) is the first DEA model that calculates total efficiency based on constant returns to scale, while the pure technical efficiency or BCC (Banker, Charnes and Cooper) model investigates local returns to scale under the assumption of VRS (Charnes *et al.*, 1994). In BCC model, there is no obligation to be constant returns to scale. Each DMU must provide both technical and scale efficiency to be CCR-efficient, while it is sufficient to provide only technical efficiency to be BCC-efficient (Bowlin, 1998).

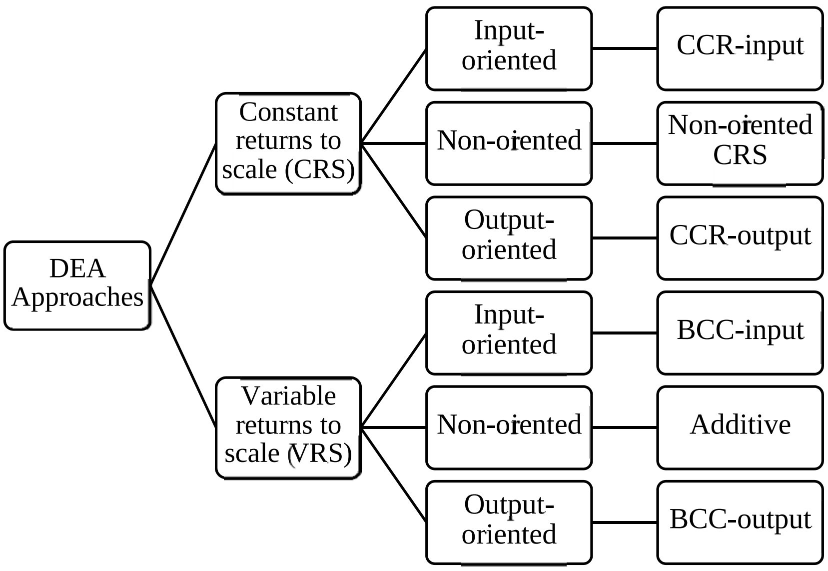

Figure 1. Classification by returns to scale and orientation (Ali, 1994)

2.4. The CCR model

The input-oriented CCR model focuses on what should be the optimum amount of input corresponding to a certain amount of output. In the CCR model, the efficiencies of DMUs are provided by the ratio of virtual outputs to virtual inputs (Soysal-Kurt, 2017).

Assume that *n* is the number of DMUs, *s* is the number of outputs and *m* is the number of inputs; the CCR model for DMU_o is as follows (Charnes *et al.*, 1978):

$$max h_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$

subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1$$

$$j = 1, \ldots, n;\ v_i, u_r \geq 0\ ;\ i = 1, \ldots, m;\ \ r = 1, \ldots, s$$

Because the model above is the fractional programming form, for facilitating the solution it is transformed into the linear programming form. The results of both models are the same. The CCR model in LP form for DMU_o is as follows (Cooper *et al*., 2006):

$$\max \theta = \sum_{r=1}^{s} u_r y_{ro}$$

Subject to:

$$\sum_{i=1}^{m} v_i x_{io} = 1$$

$$\sum_{r=1}^{s} u_r y_r - \sum_{i=1}^{m} v_i x_{ij} \leq 0$$

$$j = 1, \ldots, n;\ v_i, u_r \geq 0;\ i = 1, \ldots, m;\ r = 1, \ldots, s$$

From the model above, the efficiency scores of each DMU are obtained by generating maximization problems for all the DMUs (Soysal-Kurt, 2017). To assess the efficiencies correctly, the number of DMUs must be greater than the sum of the number of inputs and outputs three times (Raab and Lichty, 2002). v_i and u_r respectively represent the weights of each input and the weights of each output (the relative importance degrees). The equality constraint represents the sum of the virtual inputs of DMU_o. Inequality constraint states that the sum of the weighted outputs cannot be greater than the sum of the weighted inputs for each DMU (Soysal-Kurt, 2017). The objective function represents the virtual outputs of DMU_o. If the optimum value of the objective function (θ^*) is equal to 1, DMUo will be efficient. If the value θ^* is smaller than 1, DMUo will be inefficient, relatively.

The dual form of the CCR model for DMU_o is as follows (Banker *et al.*, 2004):

$$\text{minimize } \theta - \varepsilon \left(\sum_{i=1}^{m} s_i^{-} + \sum_{r=1}^{s} s_r^{+} \right)$$

subject to:

$$0 = \theta x_{io} - \sum_{j=1}^{n} x_{ij} \lambda_j - s_i^{-}$$

$$y_{ro} = \sum_{j=1}^{n} y_{rj}\lambda_j - s_i^{+}$$

$$0 \leq \lambda_j, s_i^{-}, s_r^{+} \qquad \forall i, j, r.$$

The dual model with adding slack variables contains information for inefficient DMUs about what should be done to become efficient. θ is a value between zero and one. It determines how much the input x_{io} should be reduced to θxo radially to get DMU_o to the efficient frontier (Kulshreshtha and Parikh, 2002; Cooper *et al*., 2006). The values λ_j are the density values of the elements in the reference sets that provide DMU_o to be efficient. The value s_i^{-} (input excesses) is the slack input value belonging to *i*. input of DMU_o. The value s_r^{+} (output shortfalls) is the slack output value belonging to *r* output of DMU_o (Soysal-Kurt, 2017).

According to the dual model, if the weighted inputs of relatively inefficient DMU_o are converted to $(\theta x_{io} - s_i^{-})$ and the weighted outputs of relatively inefficient DMU_o are converted to $(y_{ro} + s_r^{+})$, DMU_o will be efficient.

To determine the possible input excesses and output shortfalls, a two-stage LP model is needed (Cooper *et al*., 2007). At Stage I, the dual form of the model is solved and then the value θ^* is obtained. The value θ^* is the same as the efficiency value calculated in the primal linear model (Soysal-Kurt, 2017). The value θ^* obtained will be used at Stage II. At Stage II, using the value θ^* obtained at Stage I, the following model is solved:

$$\max_{\lambda, s^-, s^+} w = e\,s^- + e\,s^+$$

subject to:

$$s^- = \theta^* x_o - X\lambda$$

$$s^+ = Y\lambda - y_o$$

$$0 \leq \lambda j, si-, sr+$$

e = (1,…, 1) a vector whose elements equal to 1.

$$e\,s^- = \sum_{i=1}^{m} s_i^{-}$$

$$e\,s^+ = \sum_{r=1}^{s} s_r^{+}$$

The purpose of Stage II is to find a solution which makes the sum of the input excesses and output shortfalls maximum maintaining $\theta = \theta^*$. In order to be CCR-efficient with optimal solution values (θ^*, λ^*, s^{-*}, s^{+*}), DMU_o must satisfy the following two criteria (Cooper *et al.*, 2007):

i. $\theta^* = 1$

ii. All slacks (s_i^{-*}, s_r^{+*}) = 0.

But in some cases, it can be seen that only the first constraint is satisfied. In this situation, DMU_o is characterized as "weak efficient" (Soysal-Kurt, 2017).

2.5. The BCC Model

The BCC input oriented (BCC-I) model evaluates the efficiency of DMU_o, DMU under consideration, by solving the following linear program (Toloo and Nalchigar, 2009):

$$\max \sum_{r=1}^{s} u_r y_r - u_o$$

subject to:

$$\sum_{i=1}^{m} w_i x_{io} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - u_o - \sum_{i=1}^{m} w_i x_{ij} \leq 0$$

$$j=1,2,\ldots,n;\ u_o,\text{free};\ w_i \geqslant \varepsilon,\ i = 1,2,\ldots,m;\ u_r \geqslant \varepsilon,\ r = 1,2,\ldots,s$$

where x_{ij} and y_{rj} (all nonnegative) are the inputs and outputs of the *j*th DMU, w_i and u_r are the input and output weights (also referred to as multipliers). x_{io} and y_{ro} are the inputs and outputs of DMU_o. Also, ε is non-Archimedean infinitesimal value for forestalling weights to be equal to zero.

3. 3. Results and Discussions

3.1. Overall technical efficiency

The result in Table 3 presents efficiency scores derived from the CCR and BCC models for Old Oyo National Park for 15 years, along with the magnitude of overall technical inefficiency. The results indicate that the park has been characterized with much unevenness in overall technical efficiency between the period under study (2001 – 2015). The overall technical efficiency of the study area ranges between 0.67 and 1.00 with a yearly average efficiency scores of 0.95 (Table 4). This implies that if the park is efficient in its outputs instead of its current level of input, it would need only 95.00% of the same input annually.

However, the efficiency of the study area is higher than the mean efficiency of parks reported for Polish National Parks (Rusielik and Zbaraszewski, 2014) and 0.52 reported for Taiwan's industrial parks (Pai *et al*., 2017). The mean efficiency score of the study area also implies that the magnitude of overall technical inefficiency of the park was only 5.00%. This therefore suggests that, by adopting best management practices, the park can, on an average, reduce their inputs by at least 5.00% and still produce the same level of outputs. However, the potential reduction in inputs from adopting best management practices will vary from year to year. Alternatively, the park has the capacity of producing as much as 1.05 times its outputs from the same level of inputs.

Table 3. Overall Technical Efficiency, Pure Technical Efficiency, and Scale Efficiency Scores for Public Sector Banks

DMUs	CCR	OTIE%	BCC	PTIE%	Scale Efficiency	SIE(%)	RTS
DMU1	1	0	1	0	1	0	CRTS
DMU2	1	0	1	0	1	0	CRTS
DMU3	1	0	1	0	1	0	CRTS
DMU4	0.67	33	1	0	0.67	33	DRTS
DMU5	1	0	1	0	1	0	CRTS
DMU6	0.69	31	0.71	29	0.97	2.82	IRTS
DMU7	0.95	5	1	0	0.95	5	DRTS
DMU8	1	0	1	0	1	0	CRTS
DMU9	0.93	7	0.99	1	0.94	6.06	DRTS
DMU10	1	0	1	0	1	0	CRTS
DMU11	1	0	1	0	1	0	CRTS
DMU12	1	0	1	0	1	0	CRTS
DMU13	1	0	1	0	1	0	CRTS
DMU14	1	0	1	0	1	0	CRTS
DMU15	1	0	1	0	1	0	CRTS

Note: CCR = overall technical efficiency, OTIE% = Overall technical inefficiency = (1- CCR) ×100, BCC = pure technical efficiency, PTIE% = Pure technical inefficiency = (1-BCC) ×100, SE = CCR/BCC, SIE(%) = Scale inefficiency = (1-SE)×100, RTS = returns-to-scale, IRS = increasing returns-to-scale, CRS = constant returns-to-scale; and DRS = decreasing returns-to-scale

The park is considered to be very efficient when its yearly overall technical efficiency score is equal to 1.00 in the analysis. In the years when its overall technical efficiency score is less than 1.00, it is regarded as being relatively inefficient (Kumar and Gulati, 2008). From the result in Table 5, of the 15 years' interval, the park was found to be technically efficient in 11 years since it had its overall technical efficiency score to be 1.00. According to Kumar and Gulati (2008), these periods together define the best management practices or efficient frontier and, thus, form the reference set for inefficient years. This also implies that the park's resource utilization process is very functional, hence the production process of the park does not characterize any waste of inputs. Moreover, considering that the overall technical efficiency score of the inefficient years range from 0.67 in 2004 to 0.95 in 2007, it therefore implies that the park can potentially reduce its current input levels between 33.00% and 5.00%, respectively, while their output levels remain unchanged.

Table 4. Descriptive statistics of overall technical efficiency scores for Old Oyo National Park, Nigeria

Statistics	All Years	Efficient Years	Inefficient Years
N	15	11	4
Mean CCR	0.95	1	0.81
SD	0.11	0	0.12
Minimum	0.67	1	0.67
Maximum	1	1	0.95
AOTIE (%)	5	0	19
Interval	0.84 – 1.06	1	0.69 – 0.93

Source: Elaborated by the authors.

3.2. Pure technical efficiency and Scale efficiency

The result in Table 5 showing the pure technical efficiency and scale efficiency measures of the park indicates that the overall technical inefficiency (5.00%) observed in the study area could be attributed to both poor input utilization (pure technical inefficiency) and inability of the park management to operate at the most productive scale (scale inefficiency). The mean score for the pure technical efficiency of the park for a period of 15 years is 0.98 (Table 5). This implies that 2.00% of the 5.00% of the overall technical inefficiency of the park is due to the management who are not following appropriate management practices and the selection of incorrect input combinations, while the remaining 3.00% could be attributed to inappropriate scale of park operations. Moreover, the higher mean and lower standard deviation of the pure technical efficiency scores compared to scale efficiency scores indicates that a lower portion of overall technical inefficiency is due to pure technical inefficiency.

Table 5. Descriptive statistics of Overall technical efficiency, Pure technical efficiency, and Scale efficiency scores

Statistics	CCR	BCC	Scale Efficiency
N	15	15	15
Mean	0.95	0.98	0.97
SD	0.11	0.07	0.08
Minimum	0.67	0.71	0.67
Maximum	1	1	1
MTIE (%)	5	2	3
Interval	0.84 – 1.06	0.91 – 1.05	0.89 – 1.05

Notes: SD = standard deviation; MTIE = mean technical inefficiency (%) = = (1 - mean efficiency)*100; Interval = (Average efficiency - SD; Average efficiency + SD)

3.3. Returns-to-Scale

The result in Table 3 also indicates the nature of yearly returns-to-scale for the study area. The result shows that for 11 years the park was operating at the most productive scale size, thereby experiencing constant return-to-scale, while in a year it was operating below its optimal scale size and thus, experiencing increasing return-to-scale. This implies that the park can enhance its overall technical efficiency by increasing its size. The park was also observed to be operating at a decreasing return-to-scale for the remaining 3 years, which also implies that downsizing could be an appropriate strategic option for these 3 years in the park quest to reduce its unit costs. This is in accordance with the observation of Kumar and Gulati (2008) that for an institution to operate at a very productive scale (constant return-to-scale) it must minimize its inputs and maximize its outputs. Consequently, if the park is operating on a short-term basis, it may be operating in the zone of increasing returns-to-scale or decreasing returns-to-scale. Also, if they decide to operate on a long-term plan, it will move towards a constant return-to-scale by becoming either larger or smaller to survive (Cracolici, 2004; 2005; Cracolici and Nijkamp, 2006). This process might involve changes of its operating strategy in terms of scaling up or scaling down of its size of operations.

3.4. Total potential improvement

Table 6 shows the potential improvement areas in the input-output activity of the park needed for it to put its inefficient years into being efficient. The result shows that for the overall technical inefficiency of the park to be efficient, the park needs to reduce its budget by

23.00%, increase its income generation by 616.00%, reduce its staff strength, rate of offence committed and staff sent for training by 55.00%, 5.00% and 53.9%, respectively. The park will also need to increase its tourist inflow, number of interns and research conducted by 5842%, 2304% and 616% to be efficient. This is in accordance with the observation of Bosetti and Locatelli (2005), Yang and Zhoa (2009), Yu *et al*. (2014) and Pai *et el*. (2017) assertion that the total potential improvements of any institution are only feasible if all the inefficient data management units are aggregated together to provide guidelines for proper allocation of resources.

Table 6: Total potential improvement

Variables	CCR Efficiency	BCC Efficiency
Budget	-0.23	0
Income	6.16	22.25
Staff	-0.55	0
Offence	-0.05	-8.23
Training	-5.39	0
Visitors	58.42	50.49
Internship	23.04	9.52
Research	6.16	9.52

Source: Elaborated by the authors.

Furthermore, the result in Table 6 shows the total improvement needed by the park to ensure it has a pure technical efficiency across its frontier. The result indicates there must be an increase in all its outputs and 82.30% reduction in rate of offence committed in the park. This is in accordance with Charnley's (2005) and Kruger's (2005) assertion that park offences reduce the output (benefits) of the park ranging from visual amenities and the preservation of wildlife habitat to monuments and memorials. Accordingly, the rate of offence committed in a protected area determines its attractiveness to the public (Cracolici, 2005). Park offences range from poaching, illegal logging, farmland and settlement encroachment (Jacob *et al*., 2015a, b; Jacob and Nelson, 2015; Jacob *et al*., 2013; Jacob and Ogogo, 2013; Ogogo *et al.*, 2010). These offences are also a major threat to biodiversity (Hilborn *et al*., 2006; Biggs *et al*., 2013). Apart from policies such as trade restrictions, education, and financial penalties used in reducing illegal activities (Rosen and Smith, 2010; Treves and Bruskotter, 2014), the park also requires law-enforcement policies at all levels, including ranger patrols, intelligence gathering, and effective criminal justice systems (Challender and MacMillan, 2014; Tranquilli *et al*., 2014) for it to be effective and in turn improve the output of the park. Law enforcement is the best way to prevent further biodiversity erosion, and is necessary to achieve proper management of PAs as a common good (Gibson *et al*., 2005). The most promising form of law enforcement is prevention (Fischer, 2008), which in most cases means patrols within and around the protected areas. This can be performed to a certain extent in partnership with the park support zone communities.

4. Conclusion

With the calls for an increase in effectiveness and equitable management of PAs, this study shows results that can be useful for PAs managers. The study highlights the importance of applying DEA in evaluating a park's management efficiency by comparing management performance across the different years through evaluation of its outputs. This is essential as PAs managers will want to know which input or output is affected by an action and at what level.

It also showcases the park's performance and the associated problems in achieving its management efficiency. Accordingly, the methodology could be applied with some extension in other parks in the country as the approach is very effective in cases with no functional relationship between production factors. However, the approach is limited as it requires the values of all needed variables and evaluates only the relative efficiency of the study group.

This paper shows that Old Oyo National Park was efficient for about 80% of the study period with a mean scale efficiency of 97%. The park also operated at 80% of its productive scale size, thereby experiencing constant return-to-scale implying that it did exceed its optimal size. The study recommends, as a possible way for the park to improve its management efficiency at all its frontiers, the reduction in all its inputs and increasing all the park's outputs.

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OCENA EFEKTYWNOŚCI PARKU NARODOWEGO OLD OYO Z UŻYCIEM PODEJŚCIA DEA

Streszczenie

Mierzenie efektywności parku narodowego jest trudne ze względu, między innymi, na takie czynniki jak heterogeniczność dostarczonych źródeł (np. dane nt. budżetu, personelu) oraz oczekiwanych rezultatów (np. dochód, przepływ odwiedzających). Gdy tak rzecz wygląda w zarządzaniu obszarem chronionym, w innych dziedzinach podejście może być stosowane z powodzeniem przez wykorzystanie granicznej analizy danych (DEA). DEA ma kilka zalet w porównaniu z innymi technikami gdyż równocześnie wykorzystuje wielorakie heterogeniczne dane wejściowe i wyjściowe w celu określenia które projekty są najskuteczniejsze, które to określa się jako graniczny obszar skuteczności w porównaniu z innymi w zestawie danych. Dlatego też w niniejszym badaniu używa się DEA do oceny skuteczności zarządzania w Parku Narodowym Old Oyo w okresie 2001-2015. Wyniki wskazują, że park ten był efektywnie zarządzany przez 11 i 13 lat, odpowiednio, jeśli idzie o ogólną techniczną oraz czysto techniczną skuteczność w średniej skali efektywności wynoszącej 97%. Również, park ten działał w 80% swojej całkowitej skali produktywności. Te wyniki oraz użycie DEA podkreślają zarówno sukces wykorzystania tej techniki w określaniu skuteczności obszaru chronionego oraz tych czynników, które należy rozważyć przy alokowaniu źródeł przeznaczonych dla projektów realizowanych w Parku.

Słowa kluczowe: park narodowy, skuteczność, alokacja źródeł, zarządzanie obszarem chronionym

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