ANALYSIS OF ECONOMIC EFFICIENCY OF WILDLIFE LAW ENFORCEMENT IN SERENGETI ECOSYSTEM PROTECTED AREAS, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENVIRONMENTAL AND NATURAL RESOURCE ECONOMICS OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2013

ABSTRACT

Poaching is regarded to be a critical threat to conservation of protected areas in Tanzania. To date efforts to reduce poaching are relied on law enforcement techniques which are reported to require much resources. Efficiency studies on wildlife law enforcement in the protected areas are limited. This study analyzed and compared economic efficiency of wildlife law enforcement using three Decision Making Unit (DMU) of Serengeti National Park, Ikorongo/Grumeti Game Reserves and Ikona Wildlife Management Area. Three years (2010-2012) monthly data on wildlife law enforcement inputs and outputs were collected from key informants and supplemented by secondary data. Structured interview to 153 randomly selected wildlife law enforcement staff was undertaken to collect socio-economic data. Shadow prices for non-marketed inputs were estimated, and market prices were used for tangible inputs. Input-oriented Data envelopment analysis was used to estimate economic efficiency under Variable Return to Scale and Constant Return to Scale assumptions. Results revealed that under BCC model, wildlife law enforcement in all DMUs were technical efficient. Mean allocative efficiency were 78.5% (SENAPA), 87.9% (IGGR) and 97.3% (IWMA), similar to economic efficiency scores. This implies that to attain economic efficiency, input usage were to be reduced by 21.5%, 12.1% and 2.7% in that order of the DMUs. Economic inefficiency in CCR model was largely attributed by technical inefficiency than allocative. A significant negative relationship between days-off and economic efficiency in both models was observed. Likewise, positive and negative coefficients of labour under constant and variable return to scales models in SENAPA and IGGR were respectively observed, implying that increase in labour improve technical efficiencies in SENAPA and reduce the economic efficiencies in IGGR. The less inefficient observed under IWMA was attributed to sense of ownership created and participation, roles on responsibility developed through community-based wildlife management which resulted to decrease in law enforcement inputs.

It is recommended that more participatory programmes in wildlife management would lower law enforcement input usage.

DECLARATION

I, Qambemeda Masala Nyanghura, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

15/11/2013

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The above declaration is confirmed

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ACKNOWLEDGEMENTS

First and foremost, I wish to thank the almighty God for His blessings throughout the period of the study.

I wish to thank my supervisor, Dr. J. M. Abdallah for his intellectual advice, personal commitment, assistance and intensive supervision from the very beginning of this study until its completion. I also extend my sincere gratitude to Prof. Y.M. Ngaga, Prof. J. F. Kesi, Dr. F. Mombo, and Miss Innocensia Pato for their assistance, encouragement and constructive suggestions during the entire study period.

I wish also to thank the Wildlife Division for granting me a study leave. I thank Mr M. Rwegasira (Project Manager of Ikorongo/Grumeti Game reserves), Mr. A. H. Seki (Wildlife Manager of Grumeti Tourist Company), Mr. S. Msumi (Resource Protection Manager of Serengeti National Park), Mr. S. Makacha (Game Officer of Ikona Wildlife management Area), and District Magistrates of Serengeti, Bunda, Bariadi, Ngorongoro, Tarime, Magu, Meatu and Shinyanga for their immense support in collection of data in the field.

Lastly, many thanks should also go to all my classmates of MSc. Environmental and Natural resource economics 2011 for their support.

To all, I say be blessed.

DEDICATION

This work is dedicated to "The Beneficent", He who gives blessings and prosperity to all beings without showing disparity. His limitless capacity and abundance made this work possible and to my parents, Masala Nyanghura and Veronica Sanka who showed me the way to school.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADMADE	Zambia's Admistrative Management Design for Game Management Areas
AE	Allocative Efficiency
BCC	Berker, Charnes, and Cooper Model
CBD	Convention on Biological Diversity
CCR	Charnes, Cooper and Rhodes Model
CCS	Community Conservation Service
CE	Cost Efficiency
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species
CRS	Constant Return to Scale
CWM	Community-Based Wildlife Management
DAEP	Data Envelopment Analysis Program
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
EMS	Efficiency Measurement System
EWURA	Energy and Water Utilities Regulatory Authority
AA	Authorized Association
FDH	Free Disposable Hull
GPS	Global Positioning System
GTC	Grumeti Tourist Company
IGGR	Ikorongo/Grumeti Game Reserves
IIED	International Institute for Environment and Development
IUCN	International Union for Conservation of Nature

IWMA	Ikona Wildlife Management Area
MBOMIPA	Matumizi Bora ya Malihai Idodi na Pawaga
ML	Maximum Likelihood
MLE	Maximum Likelihood Estimates
MNRT	Ministry of Natural Resource and Tourism
PA	Protected Area
RE	Revised Edition
SE	Scale Efficiency
SENAPA	Serengeti National Park
SFA	Stochastic Frontier Analysis
TAWIRI	Tanzania Wildlife Research Institute
TE	Technical Efficiency
TZS	Tanzanian Shillings
UNEP	United Nations Environment Programme
URT	United Republic of Tanzania
VRS	Variable Return to Scale
WLES	Wildlife Law Enforcement Staff
WMA	Wildlife Management Area

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Wildlife is one of the natural resources of significant importance ecologically, socially and economically in Tanzania. It contributes to about 16% to the national income account mainly through consumptive (tourist hunting) and non-consumptive (photographic tourism) utilization (URT, 2009). In recognizing its importance, Tanzania devotes nearly 28% of her land to protected areas for conservation of wildlife. This involves Game Reserves (15%), Game Controlled Area (8%), National Parks (4%), and Ngorongoro Conservation Area Authority (1%) (URT, 2007). Among other things law enforcement was instituted to prevent unregulated use and disturbance of these protected wildlife areas. This involved apprehending wildlife law violators and taking them to court of law for penalty if found guilty (Lyimo and Ndolezi, 1996; Maganga, 1999).

Law enforcement can be defined as the range of procedures and actions employed by the state, its competent authorities and agencies to ensure that organizations or persons potentially failing to comply with laws or regulations can be brought or returned into compliance and or punished through civil, administrative or criminal actions (UNEP, 1999).

In the 1970's and early 1980's wildlife resource in Tanzania suffered dramatic declines due to lack of capacity to manage increasing poaching pressures (Andmile and Eves, 2009). As a result, Tanzania lost nearly half of her elephant populations and almost all black rhinoceros populations (Mboya *et al.*, 1995). Herbivore survey across Tanzania revealed that further declines in wildlife populations occurred from late 1980s to early 2000s in over 50% of the surveyed areas (Andmile and Eves, 2009).

Severe (2000) and Knap (2012) among other researchers argued that effective law enforcement operations can improve conservation of wildlife inside and outside protected areas and creates enabling environment conducive for investment which in turn enhances sustainable conservation of wildlife. Increasing wildlife loss because of poaching and high costs of wildlife law enforcement among other things have caused the government of Tanzania to resort to creation of Wildlife Management Areas (WMA), as a strategy to both slow down habitat loss and/or degradation that leads to species extinction and reduction rate and creating incentive for communities' wildlife conservation (Opyene, 2008). The approach also fosters compliance with wildlife conservation law by creating community ownership over the resource. However, establishment of WMA does not preclude strengthening of law enforcement as the livelihood surrounding the protected areas are characterized by poverty, and still depends on wild resources for their subsistence and commercial earning as their available alternative (Clark *et al.*, 1997).

Inadequate capacity to overcome poaching has been attributed to lack of community participation, and inefficiency of wildlife law enforcement as a result of un-optimal allocation of limited resource to enforce the wildlife law. Manpower, patrol equipments are among the limited input resources supplied in line with high law enforcement costs (MIDAS, 1993). Among ways to increase law enforcement efficiency is to encourage community participation in the wildlife conservation in a way that would decrease the level of input resources while maintaining output level (input-orientated) or maintaining the fixed input resources to maximize the output (output- orientated) (Dilulio, 1993; Davis, 1998).

1.2 Problem Statement and Justification of the Study

Poaching has been a critical threat to the conservation efforts of protected areas in Serengeti ecosystem for decades (Loibooki *et al.*, 2002; Nielsen, 2006; Rentsch, 2011). It is arguable that poaching in Serengeti ecosystem is relatively higher than other ecosystems of international importance in Tanzania, often attributed to a large extent by less effectiveness and efficiency of wildlife law enforcement. In spite of the fact that the Wildlife Policy of Tanzania of 2007 and Wildlife Conservation Act of 2009 highlighted the significance of wildlife protection and emphasizes the role of law enforcement to combat poaching, still poaching has not declined. Strengthening of wildlife law enforcement in Serengeti ecosystem has also been highly recommended by various researchers (Naughton, 1998; Hackle, 1999; Kalterbon *et al.*, 2005; Nielsen, 2006; Mfunda and Røskaft, 2010). However, efforts to reduce poaching still rely heavily on enforcement techniques mainly anti-poaching patrols carried out under protected area managers (Hilborn *et al.*, 2006; Holmern *et al.*, 2007; Nyahongo *et al.*, 2009).

Difference in management regimes and resource limitations causes protected areas to have different levels of law enforcement performance[1]. To-date studies related to effectiveness of the wildlife law enforcement have been carried out in different ecosystems of Tanzania (Ford, 2005; Nahonyo, 2005; Ngowi, 2011). Despite the efforts done by the Government and other stakeholders to reduce poaching, studies that evaluate and compare efficiency levels of law enforcement of various alternatives are limited. It is therefore difficult to judge the efficiency of various levels of the law enforcement.

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[1]*In the context of this study law enforcement performance specifically refers to levels of effectiveness and efficient use of wildlife law enforcement resources to combat poaching.*

One of the major considerations of performance evaluation is the impact of management regimes on the efficiency (Sezen and Gok, 2011). This study evaluated and compared wildlife law enforcement efficiency levels in three protected areas (Serengeti National Park (SENAPA), Ikorongo/Grumeti Game Reserves (IGGR) and Ikona Wildlife Management Area (IWMA) of Serengeti ecosystem in Tanzania.

This study, among other things, provided information on the impact of wildlife conservation reforms on the law enforcement efficiencies in order to highlight possible policy implications. It also provides information that can serve as a basis for budget allocation to the wildlife management and better use of government resources.

1.3 Rationale of the Efficiency Studies

Efficiency studies in recent years has gained a popular attention to several discipline as applied in hospitals, banks, law enforcement, and firm production analysis to mention few (Thanassoulis, 2001). The studies provide advice and recommendations to the decision makers and identify actions and directions which could result in more efficient and effective service delivery, organizational and operational arrangements and associated savings. Efficiency studies provide basis for sustainable resources utilization, tracking performance and best efficient allocation of resources. Policy makers have been using efficiency findings for their decision making and attain information for planning strategy (Hussein and Jones, 2001).

1.4 Objectives of the Study

1.4.1 Overall objective

To evaluate and compare wildlife law enforcement efficiency levels in three protected areas of Serengeti ecosystem in Tanzania.

1.4.2 Specific objectives

(i) To identify wildlife related restrictions enforced in three wildlife conservation regimes.

(ii) To identify and quantify wildlife law enforcement inputs and outputs under three wildlife conservation regimes.

(iii) To estimate economic efficiency of wildlife law enforcement at three wildlife conservation regimes.

(iv) To analyze factors influencing efficiency levels of wildlife law enforcement at three wildlife conservation regimes.

1.5 Hypothesis

Wildlife law enforcement is not economically efficient irrespective of variation in wildlife management regimes.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Historical Aspects of Wildlife Conservation in Tanzania

The philosophy of wildlife conservation in Africa started before colonialism when wildlife were managed by community themselves through informal procedures. Formal establishment of wildlife conservation areas and similar protected areas like forest reserves was introduced to Africa by colonialists. This was done soon after the scramble of Africa in the late 18th century. The history of wildlife conservation in Tanzania dates back to 1891 when laws controlling hunting were first enacted by the German rule (URT, 1998). These laws regulated the off take, hunting methods and trade in wildlife with some endangered species being fully protected. Colonial conservation policy used strategy of taking large tracts of land away from rural peoples for the establishment of protected areas and removing their jurisdiction over the natural resources of the land that remained with them. It's this strategy which used to establish Selous Game Reserve as the first conservation area in 1922 followed by the Serengeti Game Reserve in 1929. In 1940, Serengeti was given protected area status and a National Park was established in 1951 (Sinclair, 1995). Fences-and-fines approaches were the main policy tool for controlling and managing the protected areas on which it existed under state ownership. In this regard, local communities were seen as principal threat to wildlife and in all except a few cases, forcibly relocated and alienated from the resources they, or their chiefs, formerly had the right to own and control (IIED, 1994). The argument for this was that communities were regarded to have little knowledge, poor will, or very little ability to manage the wildlife in a sustainable way (IIED, 1994).

Soon after independence in 1961, Tanzania started to make initiatives in favour of fostering national development. The main focus was two folds: First, the state encouraged the gazettement of protected areas to promote wildlife conservation. Second, wildlife was viewed as a source of foreign exchange (URT, 2007). In a sequence of establishing protected areas, Ikorongo and Grumeti Game Controlled areas were gazetted in 1974 and upgraded to game reserves in 1994. However, post-colonial governments continued to embrace and carry on colonial preservation policies. In its struggle to preserve wildlife, therefore, the protectionist approach (fences-and-fines approach) caused skepticism, lack of trust, and even hatred between wildlife authorities and the communities in wildlife areas (Matzke and Nabane, 1996). Perceived failure of the fences-and-fines approach was mainly because of its top-down nature, and because it failed to take into account economic and other interests of local communities, or to involve them in making wildlife related decisions (Matzeke and Nabane, 1996).

In the late 1970s and early 1980s, conservationists urged to search for viable and sustainable alternatives or a "lasting solution" (Siachoono, 1995). The most appealing alternative approach was for the conservationists to retrace their own footsteps to go to rural communities (their perceived "enemies"), ask for forgiveness and promise cooperation, partnership and equitable distribution of benefits (Freeman, 1989; IIED, 1994). They named the new approach Community-Based Wildlife Management (CWM). The underlying idea is that the rural communities have been alienated from a resource they should rightfully control, manage and benefit from. The main objective for CWM is to create, through the bottom-up, participatory approach, conditions whereby a maximum number of community members stand to benefit from a sustainable management and utilization of wildlife.

In 1990s Government adopts active participatory approach in management of wildlife outside the core protected area commonly known as wildlife management areas. CWM aims to transfer to local communities the mandate of taking care of corridors, migratory routes, and buffer zones. The approach intends to ensure that local communities secure ownership/long-term use rights of land resources and benefit from it. Ikona Wildlife Management Area was one of the WMA established in Tanzania in 1998 from the former Ikona Open area. However, CWM is viewed as being complementary to conventional law enforcement. This notion is reinforced by Jachmann (1998) who has shown that the status of wildlife depends, to some extent, on financial resource allocations to law enforcement. It should be noted, however, community participatory law enforcement may reduce the transaction costs of biodiversity conservation (Jachmann, 1998).

Within WMAs the villages are given the responsibility of deciding, with appropriate professional advice, upon the forms of wildlife utilization they wish to pursue and deriving benefits from such management. Secure tenure and user rights over land and natural resources including wildlife and forest, is crucial for resource sustainability (McNeely, 1995). Local communities need the rights to self-determination, and to set their own agenda. It does put responsibility firmly in the hands of those who will earn the benefits and pay the cost (McNeely, 1995).

2.2 Legal Instruments Governing Wildlife Conservation

2.2.1 International legal instruments related to sustainable wildlife management

Wildlife management has long been regulated at the international level. Initially this was implemented through a focus on the protection of certain species or wildlife habitats. More recently, the focus has shifted to more comprehensive approaches, epitomized by the innovative features of the Convention on Biological Diversity. All these international legally binding agreements are of key importance for the review and drafting of effective national legislation on sustainable wildlife management, either because they pose limits to the sovereignty of countries in regulating wildlife use and protection, or because they call for the operationalization of specific principles, methods and processes for the management, protection and use of wildlife.

At the international level, Tanzania becomes a member of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) since 1980. This treaty aims to regulate the international trade of wildlife species, its parts and by-products. It sets international policies on trade of wildlife which include the issuance of CITES export, import or re-export permit for species listed under CITES Appendices. It prohibits the trade of CITES species unless the individuals for trade are bred in captivity in CITES registered facilities. The treaty requires member countries to designate CITES management and scientific authorities that will ensure strict implementation of CITES regulations.

Tanzania also ratified its membership in the Convention on Biological Diversity (CBD) 1996 and the Convention on the Conservation of Migratory Species (CMS) 1999. The member-countries to the CBD are obliged, among others, to conserve sites noted for rich biological diversity, develop national framework on biodiversity conservation and ensure that any use of biodiversity is sustainable and equitable. The CMS, on the other hand, requires member countries to, among others; adopt strict protection measures for migratory species, especially those categorized as being in danger of extinction, and their habitats.

2.2.2 Administration organs and laws governing conservation in Tanzania

The Ministry of Natural Resources and Tourism are primarily overseer managers of wildlife resources in Tanzania. Other parastatal organs included under Ministry of Natural Resources and Tourism are:- Tanzania National Parks Authority and Ngorongoro Conservation Area Authority established under the National Park Act CAP 282 RE 2002 and the Ngorongoro Conservation Act CAP 284 RE 2002 respectively. These organizations manage the conservation activities within National Parks and the Ngorongoro Conservation Area where wildlife are totally protected. The other organ is Wildlife Division which is responsible for the management of Game Reserves, Game Controlled Areas and all wildlife outside protected areas. Village land set aside for community-based wildlife conservation is governed by the Wildlife Conservation (Wildlife Management Areas) Regulations, 2012. These regulations provide for their establishment and management, including the control of hunting and other sustainable use. District Game Officers under the respective District Councils work in collaboration with Ministry of Natural Resources and Tourism (MNRT) to conserve wildlife outside protected areas.

Wildlife conservation in Tanzania is governed by the Wildlife Conservation Act No.5 of 2009 and wildlife policy of 2007 with its subsidiary legislations. Along with the Wildlife Conservation Act no.5 of 2009, the other statutes applied include the National Parks Act Cap 282 of 2003 and Ngorongoro Conservation Act CAP 284 RE 2002. Generally, the protection regime is both area and species specific (URT, 2013). The law is implemented through a number of regulations concerning tourist hunting, resident hunting, non-consumptive utilization, wildlife management areas, handling and export of trophies, wildlife farming, ranching and sanctuaries and wildlife protection fund (URT, 2009). It specifies boundaries of game reserves and game controlled areas, among other details.

The laws have set restrictions and liable conviction to offenders. Restrictions includes entering the game reserves, unlawful possession of weapons inside the game reserves, vegetation destruction, grazing of livestock, hunting in national parks, and unlawful possession of government trophies (URT, 2009). All these restrictions among other things aim at increasing efficiency in management of wildlife resources in the country.

Offences relating to conservation disturbance tend to be dealt with under wildlife conservation act of 2009 together with the Economic and Organized Crime Control Act CAP 200 RE 2002. Wildlife Conservation Act of 2009 provides for heavy penalties, including imprisonment of up to 30 years if contravened, depending on the gravity of the offence. The efficiency of the wildlife law enforcement in Tanzania, with reference to the Wildlife Conservation Act No. 12 of 1974, was recognized (Milliken *et al.,* 2004). With Wildlife Conservation Act no.5 of 2009 it is expected that further progress will be accomplished, in particular if there will be an optimal allocation of inputs resources.

Moreover, the Environmental Management Act, of 2004 provides the framework for sustainable management of the environment and natural resources, expressly considering fauna among environmental resources, but without addressing wildlife issues specifically. The Act outlines principles and addresses impact and risk assessments, prevention and control of pollution, waste management, environmental quality standards, public participation and enforcement (URT, 2004).

2.3 Overview of Law Enforcement

The fundamental questions for issues of law enforcement were posed by Becker (1968), who, recognizing that law enforcement is costly, asked "how many offences should be permitted and how many offenders should go unpunished". Becker concluded that the greater the expected penalty (actual penalty multiplied by the probability of detection and punishment), the greater the deterrent effect on crime. Under a set of restrictive assumptions, Becker concluded that the optimal form of deterrence is to set fines as high as possible, while reducing the level of costly monitoring. The rationale behind Becker's argument was given succinctly by Malik (1990) who argues that raising the probability of a fine is costly,. since it requires devoting more resources to monitoring and apprehending individuals whereas raising the magnitude of a fine is costless.

The concept of an "enforcement chain" provides a useful point for analyzing explicitly each component of law enforcement (Sutinen, 1987; Akella and Cannon, 2004). The effective deterrence of an enforcement regime is the product, not only of the fine and the probability of being detected, but also the subsequent steps of detection, arrest, prosecution, and conviction. Efficiency is driven by the least effective of these processes and can only be improved by addressing each constraint in turn. Despite the difficulties with each link in this chain in developing countries, much of the literature such as Becker (1968) still assume that detection is costly and that prosecution, following detection, is perfect and without cost.

2.3.1 Law enforcement costs

Not only fines are low in developing countries, but law enforcement costs tend to be high. Enforcement of access restrictions in natural resources in developing countries, beyond a typical setting, is costly, in part because the areas are large and often dense with vegetation, but also because the number of resource dependent people who enter these natural resources are largely derived by objective poverty, therefore, high costs to defend them (Baldus *et al.*, 2001). Protected areas are also characterized by high opportunity costs as many of them are agriculture productive and highly fertile land. Law enforcement requires salaries for the guards who patrol large areas, in addition to the expenses of vehicles, guard stations, and other patrol equipment. These costs form a significant fraction of many forest and park management budgets (MIDAS, 1993).

2.3.2 Rewards and incentives

There is evidence that rewards can have a considerable impact on the efficiency of wildlife law enforcement. In a study of elephant poaching and law enforcement in the central Luangwa valley in Zambia, bonuses paid was identified as the most important predictor variable affecting the number of elephants found killed illegally, above scout density, effective investigation days, total law enforcement budget and the budget related to personal emoluments (Jachmann and Billiouw, 1997). Logarithmic analysis in the same study also indicated a saturation point for the effectiveness of bonuses, whereby the effect of bonuses paid on elephants found killed became insignificantly small after approximately 5000 bonuses (Jachmann and Billiouw, 1997). This suggests that if too many rewards or bonuses are paid out then their ability to act as an incentive may be compromised. Nevertheless, the role that reward schemes can play in increasing the effectiveness and efficiency of anti-poaching activities is apparent, if set at an appropriate level to act as an incentive.

Game scouts incur an opportunity cost while monitoring, therefore the payment to the scouts must exceed these opportunity costs, even if no one is poaching (Mesterton-Gibbons and Milner-Gulland, 1998), otherwise there is considerable likeliness of corruption. The cost to scouts to participate in monitoring has to be greater than the opportunity costs because; firstly, there is a risk to scouts when encountering armed poachers. Secondly, scouts can become estranged from their community, for example in Zambia's Administrative Management Design for Game Management Areas (ADMADE) community wildlife project, residents accused scouts for poaching, stealing, fighting, witchcraft and drunkenness (Gibson and Marks, 1995). This emphasizes not only the need for sufficient wages to offset the costs encountered, but also the involvement of all community members in project implementation. Community participation in management of wildlife and provision of significant incentives to game scouts are fundamental in determining effective and efficient law enforcement. Therefore, inclusion of those parameters in efficiency estimation of wildlife law enforcement is very imperative.

2.4 Efficiency Estimation

Efficiency may be described as the association between appreciated inputs and desired outputs (Dilulio, 1993). Efficiency can also be defined as maximizing outputs from a given set of inputs, or minimizing the inputs necessary to achieve a given level of outputs (Dilulio, 1993). This indicates that while maintaining outcomes, such as products or services, at a constant level, the organization can put all of its efforts toward decreasing the resources used, such as spending less money and/or hiring fewer people.

Modern efficiency measurements begins with Farell (1957) who drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. He proposed that efficiency of a firm consist of two components: technical efficiency, and allocative efficiency. These two measures are then combined to provide a measure of total economic or overall efficiency.

Technical Efficiency reflects the ability of a firm to obtain maximum output from a given set of inputs. It refers to the ability to avoid waste. This is possible in two ways: First is by producing as much output as technology and input usage allow. The second is by using as little input as required by technology and output production (Dilulio, 1993). Further explanation of technical efficiency was provided by Koopmans (2006). A producer is technically efficient if an increase in any output requires a reduction in at least one other output or an increase in at least one input, and if a reduction in any input requires an increase in at least one other input or a reduction in at least one output. Thus, a technically inefficient producer could produce the same output with less of at least one input or could use the same inputs to produce more of at least one output. Estimates obtained in the calculation of technical efficiency are actually relative efficiency. Relative efficiency is achieved when decision making unit is rated fully (100%) efficient on the basis of available evidence if and only if the performance of other decision making units does not show that some of its inputs or outputs can be improved without worsening some of its other inputs or outputs (Cooper *et al.,* 2004).

Allocative Efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices. It also refers to the best possible utilization or distribution of the available limited resources for maximum usefulness (Jauculan, 2012). Allocative efficiency scores indicate the excess amount of inputs utilized. In other words allocative inefficiency scores indicate the amount of slacks or excess in the use of inputs. Therefore at all levels in wildlife law enforcement chain, actors are required to reduce resources used and still attain optimality in the production. Pareto optimal frontier is represented by the technically and allocative efficient decision-making units or the best performing decision-making unit made up of wildlife law enforcement outputs and inputs.

Methodologies used for measuring efficiency are categorized according to at least two criteria (Cooper *et al.,* 2000): stochastic and deterministic methods. Whereas the former make explicit assumptions with respect to the stochastic nature of the data, the latter do not. A second classification differentiates between parametric and non-parametric methods. In the parametric approach it is assumed that the boundary of the production possibility set can be represented by a particular functional form with constant parameters. The non-parametric approach on the contrary concentrates on the regularity assumptions of the production possibility set itself. Imposing some plausible restrictions on the production process the latter methods directly construct a piecewise linear reference technology or best practice frontier on the basis of observed input-output combinations.

While deterministic techniques assume full accurate measurement, stochastic techniques account for the possibility of errors in variables due to uncontrollable external factors. The main debatable question to date among researchers in the efficiency studies is about the best frontier method. This has been argued without consensus for sometimes with some group of scientist (e.g. Ferriel and Lovell, 1990; Kaparakis *et al.*, 1994; Altanbus *et al.*, 1995) advocating the parametric approach and others (e.g. Charnes *et al.*, 1978; Sherman and Gold, 1985; Seiford and Thrall, 1990; Chen and Yeh, 2000) the non-parametric approach. However, the most popular techniques are Stochastic Frontier Analysis (SFA) (Kumbhakar and Lovell, 2000), which is parametric and stochastic, and Data Envelopment Analysis (DEA) (Cooper *et al.*, 2000), which is non-parametric and deterministic.

2.4.1 Stochastic frontier analysis

The stochastic frontier, originated when Meeusen and van den Broeck (1977) and Aigner *et al.* (1977), uses econometric methods to estimate the frontier. The analysis developed in a production frontier context, where it captures effects of statistical noise and technical inefficiency. These first models concentrate on cross-sectional data and estimate technical efficiency using Maximum Likelihood Estimation (MLE).

Since early, Aigner *et al.* (1977) first estimated the unknown parameters of the stochastic frontier model using the method of maximum likelihood, method followed also widely in later decades by Green and Doyle (1995) and Coelli (1996), among others. Maximum likelihood estimation is a popular statistical method used for fitting a mathematical model to real world data. Schmidt and Sickles (1984) point out three main difficulties concerning Maximum Likelihood (ML) methods and consistency of estimates from using cross-sectional data. First, technical efficiency of a particular firm can be estimated, but not consistently. Next, distributional assumptions are required about technical efficiency in order to estimate the model and separate technical efficiency from statistical noise.

It may be incorrect to assume that efficiency is independent of the regressors. Each of these difficulties is potentially avoidable if a satisfactory panel data set is available. A panel obviously contains more information about a particular firm than does a cross-section of the data. Moreover, Schmidt and Sickles (1984) suggest that panel data will enable one to relax some of the strong assumptions that are related to efficiency measurement in the cross-sectional framework. Pitt and Lee (1981) extend the cross-sectional Maximum Likelihood (ML) technique to analyze a panel data set. Branching from this, Schmidt and Sickles (1984) apply random and fixed effects procedures on a panel toward the estimation of a stochastic production frontier in order to estimate time-invariant technical efficiency.

Although both stochastic production functions and stochastic cost functions have been widely used in empirical research, both have drawbacks with respect to measuring relative efficiency. The stochastic production frontier approach has the disadvantage that, as output is the dependent variable, only a single output production process can be modeled. This is clearly not appropriate in law enforcement which delivers a range of services or outcomes. Furthermore, it would be very difficult to construct an appropriate composite output (outcome) measure.

A particular drawback in utilizing a cost function specification to model public sector services, however, is that this requires data on total costs, outputs and input prices. While the latter are generally available for some inputs such as labour (staff), they are typically not available for capital inputs as this requires data on both capital expenditure and the units of capital utilized (Drake and Simper, 2000). A further potential drawback of the stochastic cost frontier approach is that any non-random deviations above the cost frontier will be associated with both allocative and technical inefficiency contrary to deterministic approach. Hence, the relative efficiency measures derived from parametric and non-parametric approaches are often not directly comparable.

A potential solution to these problems, but one which has not been widely used empirically, is to employ a parametric approach, but to specify and estimate a stochastic distance frontier rather than a stochastic cost or production frontier. The distance function specification has the advantages of permitting the modeling of a multi-input, multi-output production process, and being a function only of outputs and inputs. Hence, the distance function does not require data on input prices. Furthermore, as it is a function of outputs and inputs, the stochastic distance frontier produces a relative efficiency measure that is directly comparable to the measure of technical efficiency produced by Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH).

2.4.2 Deterministic frontiers (Non-parametric method)

Farrell's deterministic approach to estimating production functions spawned a number of similar formulations, each having slightly different assumptions. The two main approaches are free disposable hull (FDH), and Data envelopment analysis (DEA). FDH is not comfortable with the all assumptions[2] in the DEA framework. Convexity and/or the returns to scale assumptions seem too restrictive to some authors. In contrast, the FDH has nearly identical modeling features and properties, except that it relaxes the convexity assumption of variable return to scale (VRS). The FDH output-possibility set for panel data is similar to DEA, the FDH production set is deterministic and as indicated by its name, also allows for free disposability. When determining output efficiency from the output-possibility set, the processes is nearly identical to the DEA measures (Nagesh, 2006).

2.4.3 Data envelopment analysis

Data Envelopment Analysis (DEA) is the one of the non- parametric method which measures the relative efficiency by transforming the multiple inputs and outputs variables from similar and homogeneous decision making units (DMU) to a single virtual input and a single virtual output. As a key advantage of DEA, it readily analyzes these multiple inputs and outputs at the same time therefore, captures more specific production characteristics of each unit. These virtual input and output are computed as weighted sums where the weights are selected in a manner that each DMU has the highest possible (but no greater than unity) efficiency rating. This is achieved through the formulation and solution of a sequence of linear programs, one associated with each DMU. The DMUs that have an efficiency rating of 1.0 are deemed efficient and the convex envelope connecting them is called the efficient frontier. The DMUs inside the efficient frontier are identified as inefficient and their relative efficiency rating is less than 1.0 based on the

[2]*First, every observed production plan belongs to the production set. This makes the DEA analysis a deterministic one. Second, any unobserved production plan that is weakly dominated by another production plan is also part of the production set. This assumption allows for free disposability. The third assumption concerns the issue of combinations of production plans and has several different forms. The form of the third assumption will determine the assumed returns to scale. This will often affect the calculated levels of efficiency.*

distance from the efficient frontier. For each inefficient DMU, the point on the efficient frontier which is closest (it could be an efficient DMU or a convex combination of a few efficient ones) is identified as its reference point. It is from this reference point that best practices can be identified and transferred to an inefficient DMU in order to make it efficient (Nagesh, 2006). Kumar and Gulati (2008) stated that this benchmark model has two assumptions, input oriented (while outputs are hold constant and inputs are decreased) and output oriented (while inputs are hold constant and outputs are increased).

Selection of appropriate DEA models may depend on the conditions of the problem on hand. Types of DEA models concerning a situation can be identified based on scale and orientation of the model. If one can assume that scale of economies do not change as size of the service facility increases, then constant returns to scale (CRS) type DEA models is an appropriate choice. CRS-DEA model is the initial basic frontier model developed by Charnes *et al.* (1978), known as the CCR model, using the last initials of the developers, but now widely known as the constant returns-to-scale (CRS) model. The other basic frontier model followed CRS is the variable returns-to-scale (VRS) model, developed by Banker *et al.* (1984). This model assumes that scale of economies do not change as size of the service facility increases. Figure 1 shows the basic DEA models based on returns to scale and model orientation. These models will be referred as "Envelopment Models" (Kumar and Gulati, 2008). Since the selected input variable in most of the studies are more controllable than the outputs then, to obtain robust and more practical results, input oriented approach will be adopted to analyze efficiency of wildlife law enforcement in this study.

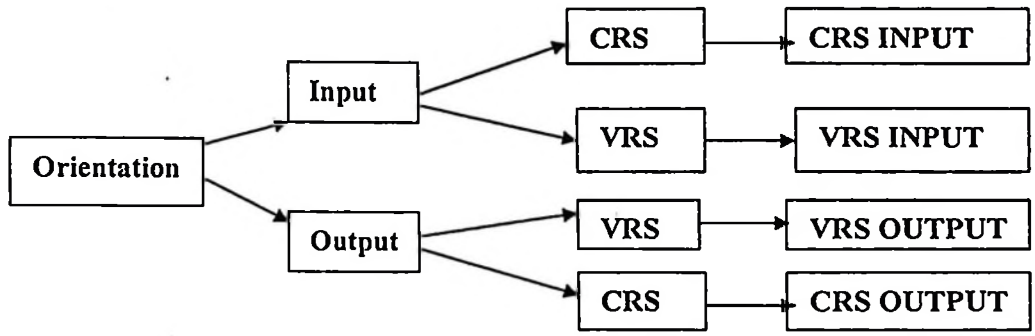

Figure 1: Basic DEA model classifications – Envelopment models

2.4.4 Experience of DEA in law enforcement efficiency

It is very unfortunately that studies on economic efficiency of wildlife law enforcement are limited, such that uses of DEA are invisible. However, the application of DEA can be observed in related studies in police field, where numbers of law enforcement efficiencies research has been done. For example, Thanassoulis (1995) examined efficiency of 41 police departments in England and Wales. Author used number of sworn officers, number of violent crimes, number of burglaries, and number of other recorded crimes as inputs. The outputs were the number of cleared violent crimes, number of cleared burglaries, and number of other recorded crimes that were cleared. The research indicated that increasing the number of personnel in the agency would help in clearing more crimes. Carrington *et al.* (1997) employed 163 police patrols in New South Wales as DMUs. The researchers used the number of sworn officers, number of civilian officers, and number of cars as inputs, while the number of crimes, arrests, summons, major car accidents recorded, and kilometers that police cars had traveled were used as outputs.

Drake and Simper (2000) investigated the comparative efficiency of the English and Welsh police agencies. Inputs used in their research included: employment cost, premises-related expenses, transport-related expenses, and capital and other expenses.

Their outputs were: the number of traffic offenses and the number of cleared crimes. In Taiwan, Sun (2002) employed DEA to measure the comparative efficiency of the 14 police divisions in Taipei city. The author collected data from Taipei municipal police department statistics between the period of 1994 and 1996. The author used four inputs: the number of sworn officers, the number of recorded burglary cases, the number of recorded offences, and the number of other recorded crime. Number of cleared burglary cases, the number of cleared offense cases, and the number of other cleared crimes where used as output. Verma and Gavirneni (2006) measured police efficiency in India's 25 states. The authors utilized total expenditure, number of sworn personnel, number of investigators, and number of investigated cases as inputs. In addition, the authors used the number of arrests, number of people charged, number of people convicted, and number of trials completed as outputs. The authors selected these inputs and outputs based on data availability and personal experience. The authors found that eleven out of the twenty-five states had efficient police agencies.

2.4.5 Efficiency ranking method

Since the early 1980s, Data Envelopment Analysis (DEA) has been used as an alternative method of classification to evaluate the relative efficiency of independent homogenous units which use the same inputs to produce the same outputs (Cooper *et al.*, 2000). However, a serious inconvenience in the utilization of DEA as a method of classification is the possibility of having units tied with relative efficiency equal to 100%. That is, units at the frontier of relative efficiency. Various authors have tackled this inconvenience using various devices to break the tie, such as crossed evaluation (Green *et al.*, 1996), super-efficiency (Anderson and Peterson, 1993) or assurance regions (Cooper *et al.*, 2000), among others.

Ranking organizational units in the context of DEA has become an acceptable approach as done in Multi Criteria Decision Analysis (MCDA) for example Belton and Stewart (1999) and Green and Doyle (1995). Ranking is a well established approach in the social sciences (Young and Hammer, 1987). It is historically much more established than the dichotomy classification of DEA to efficient and inefficient organizational units (Adler *et al.*, 2002). Sexton (1986) was the first to introduce full rank scaling of organizational units in the DEA context, by utilizing the Cross-Efficiency Matrix. Using the availability of a model in commercial software as an indication of its popularity, then the super-efficiency ranking method developed by Anderson and Peterson (1993) is the most widespread ranking method (Ebadi, 2012).

The ranking in relation to rank-scaling has the advantage that it can be tested statistically by nonparametric analysis (Friedman and Sinuany-Stern, 1997; Sinuany-Stern and Friedman, 1998; and Sueyoshi and Aoki, 2001). Andersen and Petersen (1993) solves the problem of standard DEA that many decision making units (DMU) are rated as efficient and tie for the top position in the ranking. The super-efficiency score enables one to distinguish between the efficient observations. In particular, the super-efficiency measure examines the maximal radial change in inputs and/or outputs for an observation to remain efficient, *i.e.* how much can the inputs be increased (or the outputs decreased) while not become inefficient. The larger the value of the super-efficiency measure the higher an observation is ranked among the efficient units. Super-efficiency measures can be calculated for both inefficient and efficient observations. In the case of inefficient observations the values of the efficiency measure do not change, while efficient observations may obtain higher values. Values of super-efficiency are therefore not restricted to unity (for the efficient observations), but can in principle take any value greater than or equal to unity.

2.4.6 Slacks and efficiency improvements

Correct identification of slacks is much more important in allocative efficiency analysis since they are one component of cost inefficiency, while as regards technical efficiency they are just an additional piece of information (Porcelli, 2009). Inefficiency is caused by non-effective use of the inputs and/or outputs (Cooper *et al.*, 2004). In order to find information indicating by how much and in what areas an inefficient unit needs to improve, a non-zero slack analysis is used. Such analysis can identify marginal contributions in efficiency ratings with either an additional increase in specific output amounts or decrease in specific input amounts. However, it is important to note that, slacks represent only the leftover portions of inefficiencies after proportional reductions in inputs or outputs, if a DMU cannot reach the efficiency frontier (to its efficient target), slacks are needed to push the DMU to the frontier (target) (Ozcan, 2008).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Description of the Study Area

3.1.1 Serengeti ecosystem

The Serengeti ecosystem is located between 34^0 45' – 35^0 50' E and 2^0 – 3^0 20' S. It covers approximately 27 000 km^2 straddling the boarder of northern Tanzania and southern Kenya. The ecosystem comprises of several different protected areas, namely Ngorongoro Conservation Area (8 288 km^2), Serengeti National Park (14 763 km^2), Ikorongo-Grumeti Game Reserves (IGGR) (3 767 km^2), Maswa Game Reserve (2 200 km^2), Kijereshi Game Reserve, Loliondo Game Controlled Area and Ikona WMA (242.3km^2). The ecosystem harbours some 1.3 million wildebeest (*Connochaetes taurinus*), 200 000 zebra (*Equus burchelii*), and a vast number of ungulates and carnivores (TAWIRI, 2010). The area is characterized by the seasonal migration of wildebeest (Sinclair *et al.*, 2008). It is during the north migration that the herds often transgress the protected area boundaries and enter areas of low protection with comparatively high human population densities of the western corridor.

Reasons of selecting the study area

Serengeti ecosystem is one of the recognized international ecosystems, arguable to be threatened by poaching than any other ecosystem of international importance in Tanzania. It is the only ecosystem in Tanzania where all types of wildlife protected areas with different management approaches existed. In Serengeti National Park, management of wildlife is relatively relied on wildlife law enforcement, complemented by passive participatory approach through Community Conservation Service (CCS). In IWMA, law enforcement is complemented with active participatory approach of local community in the framework of CWM. However, the participation of local community in management of wildlife in IGGR is not well centralized at reserves level. Therefore, because of limited time and funds, the study was carried out in the mentioned three wildlife protected areas which are bordered to each other but managed under different approaches.

3.1.1.1 Serengeti National Park

Serengeti National Park (SENAPA) lies in the northern Tanzania, west of the great rift valley, between 1^0 30'- 3^0 20' south, $34^0$00'- $35^0$15' east and covers an area of 14 763 km. It is 130 km west-northwest of Arusha, Tanzanian's main northern town. A western arm extends close to the eastern shore of Lake Victoria and northern section joins the international boundary abutting Kenya's Masai-mara game reserves. The Park lies within the administrative regions of Mara, Arusha, and Shinyanga. It is contiguous to the south-east by Ngorongoro conservation area, to the south-west lies Maswa game reserve, and to the western it borders Ikorongo/Grumeti game reserves, to the north-east lies Loliondo game control area. Together, these areas form the larger Serengeti ecosystem.

3.1.1.2 Ikorongo/Grumeti Game Reserves

Ikorongo/Grumeti Game Reserves (IGGR) lie north-west of the of the Serengeti national park. The game reserves cover an area of about 1867 and 1900 km^2 respectively. The two game reserves cover an area of about 14 % of Serengeti ecosystem, and are bordered by at least 23 villages. Thus the reserves form a buffer zone to the western part of Serengeti national park. Administratively, the geographical scope of the two game reserves is taken to include the Serengeti (Ikorongo) and Bunda (Grumeti) districts of the Mara Region, northern Tanzania. The reserves lie between Latitude 2^0 4' to 20 10.5' S and Longitude $33^0$57' to 340 38' E (Grumeti), and latitude 1^0 50.5' to 20 12' S and longitude 34^0 39' to $34^0$49' E (Ikorongo). Government notices number 214 and 215 that were published on

1994 upgrade both Ikorongo and Grumeti to the game reserves status from the former game controlled area.

3.1.1.3 Ikona Wildlife Management Area

Ikona Wildlife Management Area (IWMA) is located at the western part of Serengeti corridor, in Serengeti District. It lies between 34^0-36' E and $1^0$15' - $3^0$30' S. Ikona WMA, formally known as Fort Ikoma open area covers an area of 242.3 square kilometers. The area is managed by the communities of Robanda, Natta Mbiso, Makundusi, Parkinyigoti and Nyichoka villages. Ikona WMA borders some protected areas, The Serengeti national park borders Robanda village which in turn borders the WMA partly on the south and south-east; Grumeti game reserve partly borders the ikona WMA on the south and southwest; Ikorongo game reserve borders the ikona WMA on the east and north-east.

3.1.2 Vegetation and wildlife

A great diversity of species and high patterns diversity characterize the vegetation of the Serengeti ecosystem. The major vegetation types are grasslands, woodlands and forests (Herlocker, 1976). There are many small rivers, lakes, and swamps throughout the park. Serengeti has the largest concentration of wildlife in the world. It supports over four million animals and birds, making it one of the largest animal's sanctuaries in the world. It is the best known for its unrivalled herd sizes of wildebeest, zebras, Thomson's gazelle, lion, cheetah and spotted hyena. Other animals include leopard, cheetah, elephants, rhinoceros, hippopotamus, giraffe (used as a symbol of the national airline), buffalo, waterbuck, bushbuck, Oryx, reedbuck. The area is also famous for its large number of species of rodents, bats, golden jackal, striped jackal, mongoose, otter, Grant's gazelle warthog and primate species. Smaller predators include bat-eared fox. Some of the birds found here include ostrich and flamingo.

3.1.3 Climate and rainfall

The Serengeti's climate is usually warm and dry. The main rainy season is from March to May, with short rains falling from October to November. The amount of rainfall increases from about 508 mm on the plains in the lee of the Ngorongoro Highlands to about 1200 mm on the shores of Lake Victoria. All is lush and green after the rains, but a gradual drying up follows which restricts plant growth and encourages the animals to migrate in search of permanent waters. With altitudes ranging from 920 to 1850 meters, mean temperatures vary from 15 ^{0}Cto 25 ^{0}C. It is coldest from June to October, particularly in the evenings.

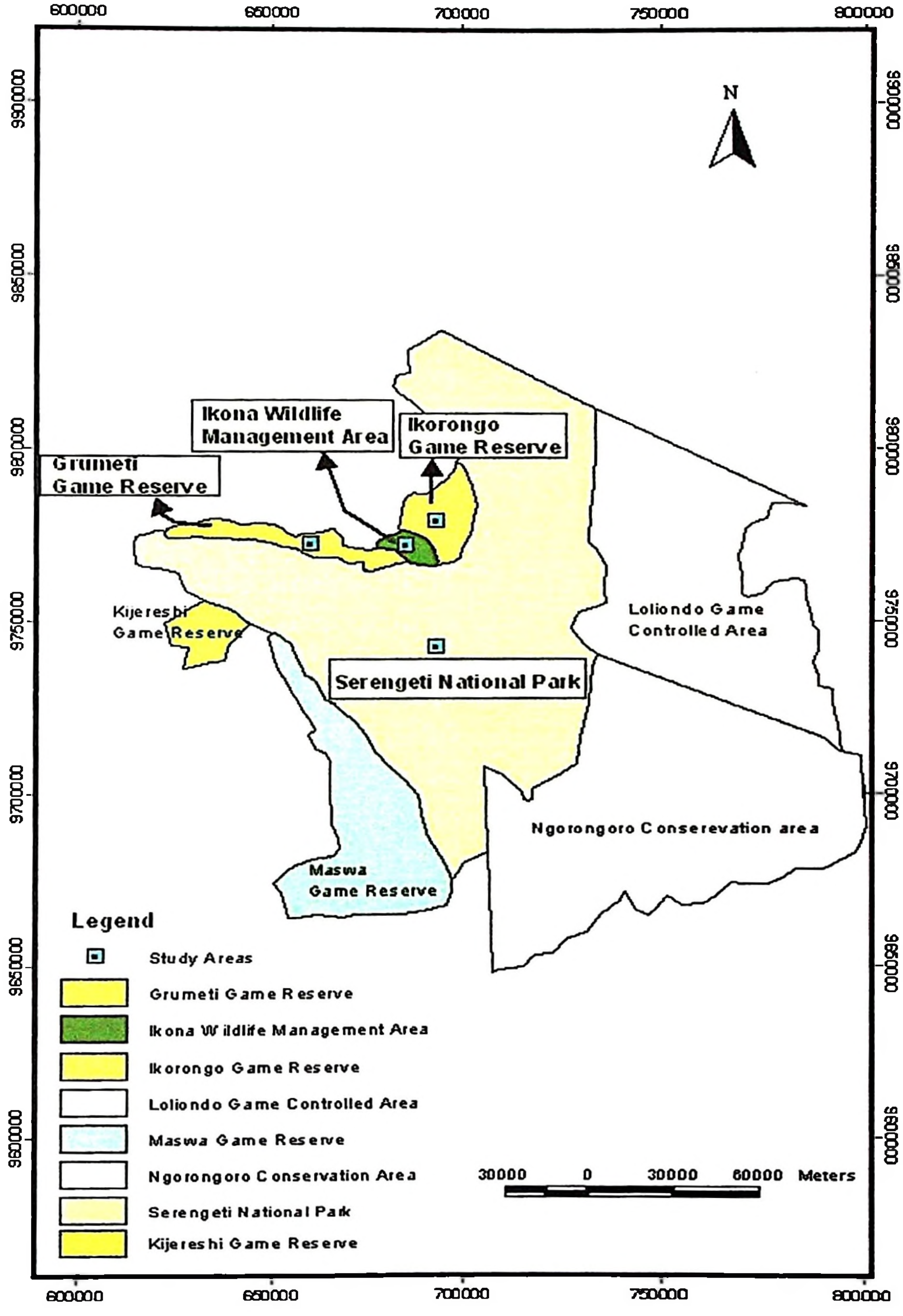

Figure 2: The Map of Serengeti Ecosystem Protected Areas Showing Study Areas

3.2 Data Collection

3.2.1 Research design

The study employs cross-sectional design suggested by De vaus (1993). The cross-sectional research design allows collection of information at one point in time that may be used in descriptive analysis and for determination of relationship between variables (Bailey, 1998). Nature of the required data justifies the use of selected design.

3.2.2 Sampling size

The sample size was determined based on the number of wildlife law enforcement staff in each DMU (Table 1). The following formula according to Yamane (1987), cited by Ngowi (2011) was used;

$$n = \frac{N}{1 + N(e^2)} \qquad (1)$$

Where; n = sample size

N = population size

e = sampling error (10% was used)

To ensure every rank[3] in a DMU is contacted for interview, the total sample size obtained in the DMUs were distributed according to the proportion of each rank level. In order to avoid biasness, simple random sampling technique was then used in each rank group to select the wildlife law enforcement staff for interview. The sampling frame used for this study was the staff registers containing the list of staff.

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[3] *In the context of this study, rank level were treated as stratum*

Table 1: Distribution of sample size in three DMUs

DMU	Rank of the WLES	Number of WLES	Sample size	Sample size %
SENAPA				
	Senior Park Warden (SPW)	3 (0.9)	1	1.3
	Park warden I (PWI)	4 (1.2)	1	1.3
	Park warden II (PWII)	8 (2.4)	2	2.6
	Senior Park Ranger (SPR)	10 (3.0)	2	2.6
	Park Ranger I (PRI)	10 (3.0)	2	2.6
	Park Ranger II (PRII)	69 (20.6)	16	20.8
	Park Ranger III (PRIII)	21 (6.2)	5	6.5
	Park Ranger IV (PRIV)	210 (62.7)	48	62.3
	Total	135	57	100
IGGR				
	Game Officer (GO)	2 (1.5)	1	1.8
	Game warden (GW)	13 (9.6)	5	8.8
	Wildlife officer (WO)	3 (2.2)	1	1.8
	Patrol leader (PL)	5 (3.7)	2	3.5
	Assistant Patrol leader (APL)	16 (11.9)	7	12.3
	Game scouts (GS)	70 (51.9)	30	52.6
	Other Staff (OS)	26 (19.3)	11	19.2
	Total	135	57	100
IWMA				
	Game officer (GO)	1 (4.3)	1	5.3
	Game scouts (GS)	22 (95.7)	18	94.7
	Total	23	19	100
	Overall Total	492	153	31.1

WLES –Wildlife law enforcement staff. Numbers in brackets are percentages.

3.2.3 Primary data

3.2.3.1 Checklists and data forms

Checklists (Appendix 6 and 7) were used as guide for interview in collection of monthly input and output data for three years (2010-2012) from the key informants (Chief Park Warden from SENAPA, Project Manager from IGGR, IWMA Secretary, and Wildlife Manager of Grumeti Tourist Company). Other key informants were court magistrate of Serengeti, Bunda, Bariadi, Ngorongoro, Tarime, Magu, Meatu and Shinyanga Districts for collection of output information. The basis of using three years was the availability of data. Responses were filled in designed data form (Appendix 8 and 9).

3.2.3.2 Questionnaire survey to law enforcement staff

Factors influence efficiency levels of wildlife law enforcement were collected from wildlife officer/rangers through questionnaires survey (Appendix 10). The questionnaire was designed to collect information on socio-economic variables such as age of personnel (years), experience of personnel (years) and education proxied by years of formal schooling. Other variables collected were number of rest-days offered/month (days), incentives[4] offered (TZS)/month, and labour (patrols man-days)/month; these variables were used to determine factors influencing the estimated efficiency levels in the study area.

Prior to the main survey, preliminary survey was conducted to pre-test the questionnaire before final administration to ascertain validity of the question and adjustment was done accordingly. The questionnaire was administered by the researcher.

3.2.3.3 Market survey

Market survey was implemented in Serengeti district using a checklist (Appendix 11) to determine the price of inputs (fuel and meal ration). Other inputs with no market price were estimated based on shadow pricing and opportunity costs. Since price of fuel (diesel) fluctuated monthly and was difficult for the respondents to recall, the data were triangulated with monthly prices (indicative price) of diesel collected from Serengeti

[4] *Incentives are defined as inducement designed and implemented to influence or to motivate people to act in a particular way (Emerton, 1999). For the purpose of this study, incentives will involve direct value to which the DMU awards to her law enforcement staff. E.g. the money in Tanzanian Shillings (TZS) given for each wire snare destroyed.*

District at Energy and Water Utilities Regulatory Authority office (EWURA, 2012). Price of every meal item consumed by wildlife law enforcement staff in each DMU was collected from market survey and aggregate cost incurred for meal quantity per month was presented in TZS.

3.2.3.4 Identification and quantification of input and output

The estimation of efficiency requires not only a careful choice of the sample size but also a good quantification of the number of inputs and outputs (Magnussen, 1996). This study attempted to incorporate a fairly comprehensive list of inputs and outputs which reflected the general scope of wildlife law enforcement activities at that particular time in order to obtain informative and robust results. However, DEA operates more powerfully when the number of DMUs exceeds total number of inputs and outputs by at least twice (Banker and Morey, 1989; Drake and Howcroft, 1994). To account for this limitation, this study used monthly inputs and output data for year 2010 - 2012, *i.e.*36 months.

Selection of inputs[5] and outputs[6] were based on conceptualization, related literature review, possibility of data availability and personal experience. Since studies of law enforcement efficiency in conservation field were limited, more experience was collected from law enforcement efficiency in police force field. Inputs collected were personnel (number of law enforcement staff), number of equipments used (vehicles), fuel (litres)/month, meal/ration (kg)/month, frequency of court attendance for witnessing/month, frequency of prosecution/month and other inputs. Outputs collected were numbers of poachers arrested per month and number of wildlife cases cleared per month. However, other fixed inputs like houses, computers and patrols gears were not

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[5] *An input may be defined as any resource used per month to generate an output*
[6] *An output is any product or service generated by the unit resulted from input (Dilulio, 1993)*

included in efficiency estimation even though the data was available. The existing literature suggests that such data should not be used for efficiency analysis because there is no quantifiable data on its impact to law enforcement function (Thanassoulis, 1995; Drake and Simpler, 2000; Sun, 2002).

Table 2: Definitions and measurement of input and output variables

Variables	Definition and measurement
Inputs	
Personnel	Monthly number of law enforcement staff (vary in ranks for each DMU)
Vehicles	Monthly number of patrol cars
Fuel	Monthly liters of diesel consumed
Meal/Ration	Monthly amount of food components[7] consumed in kg
Witnesses attendance to court proceedings	Monthly frequency of attendance to court for witnessing
Prosecution of wildlife cases	Monthly number of days used for prosecution of wildlife cases
Other inputs	Number of patrol gears (GPS, Tents, Night goggle vision, Camera, uniform, radio calls) and fire arm
Outputs	
Poachers arrested	Monthly number of poachers arrested
Wildlife cases cleared	Monthly number of wildlife cases cleared (includes conviction and un-conviction)

3.2.3.5 Shadow pricing for wildlife law enforcement inputs

When markets for a certain input are distorted, shadow pricing is used to improve the measure of value. Where no market price exists, a proxy value may be available.

[7]*Estimation of meal components was done by converting local units (debe, tins, bags etc) into standards Kg. Thus, Aggregate component of the meal consumed per month was quantified in kilogram. To ensure uniformity on weighing, cooking oil was estimated by 1litre = 1kg.*

Alternatively, where no proxy is available, a measure of value had to be derived using more complex methods. Inputs with no market price were valued by using shadow pricing and opportunity cost as described in Table 3

Table 3: Shadow pricing of wildlife law enforcement inputs

Inputs	Shadow pricing (TZS)
Personnel	Basic monthly salary
Vehicles	Monthly maintenance costs
Witnesses attendance to court proceedings	Daily allowance paid to attend the court for witnessing
Prosecution of wildlife cases	Daily allowance paid to public prosecutor recruited by DMU.

Total costs for each input used per month were collected as a nominal price in TZS from the key informants and supplemented by monthly and annual reports. Specifically, salaries were obtained from salary slips and payment vouchers. Where I didn't find payment documents, estimates were done by the help of key informant based on his/her experience. Percentages of annual salary increment were used to determine salary of other months. Exceptionally, Game officers (GO) and Game wardens (GW) of Ikorongo/Grumeti game reserves receive a monthly allowance ranging from 245 000 to 350 000 and 175 000 to 250 000 TZS respectively. To incorporate these costs, minimum amount was adopted and added to the basic monthly salaries. Thus, monthly basic salaries of GO and GW in this study were result of top-up of 245 000 and 175 000 TZS respectively. To obtain the unit costs, total costs were divided by the corresponding input units and presented in TZS.

To take care of inflation, nominal prices were deflected to January, 2010 constant price as the base month, using monthly Consumer Price Index obtained at National Bureau of

Statistics (NBS, 2012). The reason for choosing January, 2010 was the fact that this study used data collected from that month. The following formula were used for deflection;-

$$\text{Real Price} = \text{Current nominal price} \times \frac{\text{Consumer price index of the base month}}{\text{Consumer price index of the current month}} \quad \ldots\ldots\ldots\ldots(2)$$

3.2.4 Secondary data

The use of secondary data in this study was very imperative especially to supplement field base data on input and output variables. Official records namely, monthly and annual reports, were used to supplement inputs. Output (wildlife cases cleared) was supplemented from case files and courts registers. Other secondary data includes wildlife related laws and regulations, scheme of service, and other relevant reports from the office and literature.

3.3 Data Analysis

3.3.1 Descriptive statistics

Most of the data obtained from questionnaire survey were compiled coded, and then entered in the computer using Statistical Package for Social Science (SPSS version 16) software. Descriptive analysis was then carried out to obtain mean, frequencies and percentage. Wildlife law enforcement inputs, outputs and cost of inputs were summarized into mean and range in Microsoft excels and further in DEA.

3.3.2 Data envelopment analysis

DEA was used to estimate efficiency score of each DMU using inputs, outputs and corresponding cost of unit input with two assumptions of DEA. Constant Return to Scale (CRS) or CCR model assumption and Variable Return to Scale (VRS) or BCC model assumption were used in calculation of technical and scale efficiencies

(Fare *et al.*, 1994a). The models were then extended to account for cost and allocative efficiencies (Fare *et al.*, 1994b). Data Envelopment Analysis Program (DEAP) software version 2.1 package developed by Coelli (1996) was used for mathematical computations. Since inputs variable were seemed to be controlled by the management of DMUs comparatively to outputs, this study considered input-oriented DEA model which aims at minimizing inputs with given set of outputs. The use of DEA model in this study based on the justification that it analyzes multiple inputs and outputs at the same time therefore captures more specific characteristics of each unit input.

3.4.2.1 The empirical DEA model

As proposed by Charnes *et al.* (1978), input-oriented DEA model which assumed Constant Returns to Scale (CRS) was performed to compute the relative efficiency of each DMU by comparing it to all the other observations in the sample. Using duality in linear programming the following model was used to calculate the technical efficiency (Farrell, 1957):-

$\text{Min}_{\theta,\lambda}\ \theta,$

St $-y_i + Y\lambda \geq 0,$

$\theta x_i - X\lambda \geq 0,$

$\lambda \geq 0,$ ....(3)

Where; θ is a scalar and λ is Nx1 vector of constants.

x_i and y_i are respectively vectors of input and output in a particular DMU.

X and Y are respectively input matrix and output matrix which represents data of all N DMU's.

N is the number of DMUs.

The value of θ obtained will be the efficiency score for the i-th DMU. It will satisfy $\theta \leq 1$, with a value of 1 indicating point on the frontier and hence technically efficient DMU. The linear programming problem must be solved N times, once for each DMU in the sample.

The CRS assumption is only appropriate when all DMU operate at an optimal scale. Constraints in the operating environment, for instance, imperfect competition, financial and human resource constraints, amongst other factors, may cause a DMU to operate at non-optimal scale (Coelli, 1996). Moreover, the use of the CRS specification when not all DMUs are operating at the optimal scale will result in a measure of technical efficiency which is confounded by scale efficiency. Banker *et al.* (1984) suggest an extension of the CRS DEA model to provide for Variable Returns to Scale (VRS) situations. The use of the VRS DEA specification permits the calculation of scale inefficiency. The CRS linear programming problem was modified to account for VRS by adding the convexity constraint: $N1'\lambda = 1$ to equation (2) where N1 is an Nx1 vector of one's (Coelli, 1996). This approach forms a convex hull of intersecting planes which envelope the data points more tightly than the CRS canonical hull and thus provides technical efficiency scores which are equal to or greater than those obtainable by means of the CRS model.

$\text{Min}_{\theta,\lambda}\ \theta,$

St $-y_i + Y\lambda \geq 0,$

$\theta x_i - X\lambda \geq 0,$

$N1'\lambda = 1$

$\lambda \geq 0,$ ....(4)

With respect to the case of VRS cost minimization (which aims at estimating the cost-minimizing input quantities for a given input price vector), the input oriented DEA model in (3) was performed using the following equation;-

$$\begin{aligned} &\mathrm{Min}_{\lambda,x_i}\ w_i x_i^*, \\ &\mathrm{St}\ \ -y_i + Y\lambda \geq 0, \\ &\quad x_i^* - X\lambda \geq 0, \\ &\quad N1\lambda = 1 \\ &\quad \lambda \geq 0, \end{aligned} \qquad (5)$$

Where w_i is a vector of input prices for the i-th DMU and x_i^* is the cost minimizing vector of input quantities for the i-th DMU, given the input prices w_i and the output level yi.

The total cost efficiency (CE) or economic efficiency of the i-th DMU is then obtained by

$$CE = w_i x_i^*/w_i x_i \qquad (6)$$

Whereas allocative efficiency (AE) is obtained by

$$AE = CE/TE \qquad (7)$$

3.3.3 Super-efficiency analysis

Efficiency Measurement System (EMS) Software Version 1.3 was used to run super-efficiency for technical efficient DMUs obtained under BCC model assumption. Analysis focuses on ranking the DMUs from the most relatively efficient to less efficient.

3.3.4 Censored regression analysis

Censored regression model (or Tobit model) was used to analyze factors influencing efficiency level of wildlife law enforcement. STATA software version 10.1 was used to run analysis. The reason for using a censored model was the dependent variables (relative efficiency scores) was by definition bounded by 0 and 1 violating the basic assumption of linear regression model (Sigelman and Langche, 1999). This can be generally formulated in terms of an index function:

$Y^*_i = X_i \beta + \varepsilon_i$.. (8)

Where; $Y_i = 0$ if $Y^*_i \leq 0$ and $Y_i = Y^*_i$ if $Y^*_i > 0$ and $\varepsilon_i \sim N(0, \delta^2)$, X_i is the vector of exogenous variables and β a vector for unknown parameters. Y^*_i denotes the latent variable and Y_i as DEA relative efficiency scores.

Applied to wildlife law enforcement the censored regression model for analysis was:

$Y^*_i = \beta_1 + \beta_2 INCTV + \beta_3 RSTD + \beta_4 LAB + \ldots\ldots\ldots\ldots + \varepsilon_i$.. (9)

Where INCTV denotes incentives offered to law enforcement staff; For the purpose of this study incentives was considered as amount of money (TZS) to which DMU provide to her law enforcement staff to motivate them, hence positive efficiency were expected. RSTD represents number of days offered for the law enforcement staff to rest per month. It was expected that, since law enforcement activities are energy intensive work then provision of less rest days would decrease efficiency. LAB represents labour proxied by the number of patrol man-days per month. It was expected that higher labour would have positive influence on efficiency.

3.4 Study Limitations

The goal of this research was to evaluate and compare the economic efficiency of wildlife law enforcement in Serengeti ecosystem protected areas namely, SENAPA, IGGR and

IWMA. However, not all variables were included in the analysis because of unavailability and sensitivity of the data. For example, inputs for wildlife law enforcement, like firearms and inputs associated with intelligence were difficult to obtain because of its security sensitiveness. Moreover, it was observed that not all information such as poaching criminals was reported and recorded accordingly especially in IWMA. Thus, the study uses only available inputs and outputs.

This study used three DMUs which were less than appropriate number of DMUs suggested by pioneers of DEA, which is at least twice the total number of inputs and outputs deployed. This is because of limited time and funds.

It was believed that socio-economic factors of wildlife law enforcement staff such as age, education and experience may influence efficiencies of wildlife law enforcement. Though these data were collected, they were not accounted for factors of inefficiency due to the fact that their variation has to be treated annually and its corresponding possible dependent variable which is annual estimated efficiency of wildlife law enforcement are few (only three from three DMUs for three years), therefore difficulty to justify any outcome.

Additionally, researches regarding economic efficiencies related to wildlife law enforcement were limited. Thus, it was difficult to access relevant materials partnering to the theme of this study.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Wildlife Related Restrictions

The study identifies eight conservation related restrictions (Table 4) used by the three DMUs (SENAPA, IGGR and IWMA). The restrictions were similar in all DMUs; varying in magnitude when it comes to offence. About 62.5% of the identified restrictions were treated as economical case/offence[8] which called for heavy penalties. Proceedings for these kind of cases takes long time due to the fact that district courts has no jurisdiction power to attend them, unless with consent form director of public prosecutor (Section 26 (1) of Economical and Organized Crime Control Act, 2002), procedures which might take some times and therefore gave a room for corruption and even some of offenders to repeat the offences (Ngowi, 2011). Some 50% of the restrictions were treated as criminal case/offence[9].

Accordingly, contradictions between the conservation legislations on the magnitude of offence from similar restriction were observed. For example Section 17(1) and (2) of Wildlife Conservation Act No. 5 of 2009 cite that is an offence to posses weapons inside the Game reserves without the written permission of the Director of Wildlife, and on conviction shall be liable to a fine not exceeding two hundred thousand shillings or to imprisonment for a term not exceeding three years or to both. Similarly, in Section 24 (1) (b) of National Parks Act Cap 282 it is stated to be unlawful to posses weapon in National parks, with liable on conviction to a fine not exceeding twenty thousand shillings or to imprisonment for a term not exceeding two years or to both.

[8] *With reference to section 56 (1) of Economical and Organized Crime Control Act CAP 200 RE 2002, any offences prescribed in the first schedule to this Act shall be known as economic offences and triable by the Court in accordance with the provisions of this Act.*

[9] *Refers to any offence not prescribed in the first schedule of Economical and Organized Crime Control Act CAP 200 RE 2002.*

Moreover, paragraph 14 (d) of the first schedule and section 57(1), 60(2) of the Economical and Organized Crime Control Act CAP 200 RE 2002 cite the possession of weapons as economic case in Game Reserves and criminal case in National Parks. Unless the contradictions are solved, the loophole may be taken as a motive behind poaching in national parks.

Table 4: Restrictions and its offence category

No.	Wildlife related restrictions	Category of offence	
		EC	CC
1	Unlawful entering into the protected area (PA)		√
2	Unlawful possession of weapon[10] inside the PA	√	√
3	Unlawful grazing livestock inside the PA		√
4	Unlawful hunt, burn, capture, kill, wound or molest any animal	√	
5	Unlawful possession of Government trophy	√	
6	Unlawful vegetation destruction[11] inside the PA		√
7	Unlawful collection of sand, prospect or mine inside the PA	√	
8	Other restrictions[12]	√	

Key; EC – Economical case, CC – Criminal case

4.2 Wildlife Law Enforcement Inputs and Outputs

4.2.1 Wildlife law enforcement inputs

4.2.1.1 Personnel (wildlife law enforcement staff)

Results revealed that personnel were the most basic input in wildlife law enforcement operations. As a primary function, they are obligated to carry out anti-poaching patrols that involve detection and apprehending poachers. Variations in number of wildlife law enforcement staff with different ranks were noted within and between DMUs. Between the DMU, Table 5 shows that SENAPA on average has 292 number of law enforcement

[10] *Weapon is defined as per wildlife conservation Act no.5 of 2009*

[11] *Vegetation destructions includes bush/grass fire, cut, burn, injure or remove any standing tree, shrub, bush, grass, sapling seedling or any part thereof in PA.*

[12] *Unlawful dig, lay, or construct any pitfall, net, trap, snares, or use other device what so ever capable of killing, capturing or wounding any animal.*

staff, IGGR (134) and IWMA (23). Assuming all personnel patrols at a time, then average personnel to area ratio is 1:50.6 km^2 (SENAPA), 1:28 km^2 (IGGR) and 1:10.53 km^2 (IWMA).

Table 5: Wildlife law enforcement inputs; monthly mean estimates

Inputs	DMU		
	SENAPA	IGGR	IWMA
Personnel (Number of WLES)	292	134	23
Meal/Ration (kg)	3029.94	3641.40	298.40
Patrol vehicles (Number of vehicles)	34	9	2
Fuel/diesel (litres)	14 368.4	6 868.8	1 184.4
Witnesses attendance to court proceedings (frequency of attending court proceedings)	67	10	-
Prosecution of wildlife cases (days of wildlife cases prosecution)	32	11	-
Other inputs[13]	392	132	4

Key; WLES- Wildlife Law Enforcement Staff.

4.2.1.2 Meal ration

Law enforcement operations are energy demanding work, therefore, quantity and quality of meal to law enforcement staff are imperative. Effectiveness and efficiency of law enforcement especially detection and apprehension depends on, amongst others, supply of enough meal/food. Table 5 show that wildlife law enforcement staff of IGGR consumes 3641.40 kg of ration per month which is provided by Grumeti Tourist Company. Likewise, game scouts from IWMA they got 298.40kg of ration per month from their office. To SENEPA, management provides 3029.94kg of ration per month to only 125 law enforcement staff of Moru (64), Ndasiata (41) and Nyamarumbwe (20) posts which constitute about 43% of the total law enforcement staff. (For the detail consumption item Appendix 3).

[13] *Other inputs include GPS, Night goggle vision, Uniforms, Radio calls, Camera, Binoculars, and tents.*

4.2.1.3 Vehicles and fuel

All DMUs use vehicles during patrol. The vehicles were used for anti-poaching patrols, to send the arrested poachers to the police as well as sending the staff as witnesses to the court. Table 5 shows a mean number of 34 vehicles in SENAPA; nine in IGGR and two in IWMA that were available for law enforcement operations. Types of vehicles used were Toyota Land-cruiser pickup, TDI 110 Land rover pickup and TDI V1 Land-rover - Puma.

All vehicles were using diesel with mean monthly consumption of about 422 liters per vehicle in SENAPA, 763 in IGGR (where 96.9% is supplied by GTC) and 592 litre per vehicle in IWMA. The variation could probably be due to difference in budget allocation or difference in resource management. For example, SENAPA limit fuel usage to 400 litres per vehicle per month while to IGGR there were no limitation in use of fuel in GTC, refueling were done any time when needed. Fuel to the vehicles were used in anti-poaching patrols, to send the arrested poachers to the police, to send the witnesses to the court, to control problem animal, collection of salaries from head office and other administration activities. Other uses include social activities like handling sick staff and allocation of staff to check points.

4.2.1.4 Witness attendance to the court proceedings

Legal proceedings are required in order to determine whether a person is guilty or not. During this process wildlife law enforcement staff is required to attend or bring witness before the court of law. It was revealed that all DMU were responsible to send their staff to the court. Results show a monthly mean attendance of 67 frequencies[14] in SENAPA, 10

[14] *In the context of this study, frequencies means attendance level of wildlife law enforcement staff in the court proceedings, it captures the repetition attendance of individual more than once.*

frequencies in IGGR and none in IWMA (Table 5). Higher attendance level in SENAPA than for IGGR was attributed to number of cases submitted to the court. Zero attendance was reported in IWMA probably because solving of some wildlife offences (non-trophy offences) in IWMA were mostly relied on by-laws settled by Authorized Association (AA). For example poachers arrested from charcoal making or entrances inside the IWMA were to be submitted to respective village authority for punishment. However, other trophy offences were mostly handled by IGGR officials.

4.2.1.5 Prosecutiou of wildlife cases

The shortage of public prosecutors and specifically with no wildlife professions in the court has been mentioned as one of the challenges facing wildlife law enforcement in Tanzania, and hence contribute significantly not only in tardy clearance of cases but also distortion (Ngowi, 2011). SENAPA recruited three (3) public prosecutors, and allocated one to Serengeti, Bunda, and Shinyanga magistrate district respectively. Table 5 shows on average 32 and 11 days were used for prosecuting wildlife cases related to SENAPA and IGGR respectively.

4.2.1.6 Other wildlife law enforcement inputs

Other inputs identified were anti-poaching field gears such as Global Position System (GPS), Night vision goggle, uniforms, radio-calls, camera, binoculars, and tents (Table 6). While nothing was possessed by IWMA, details on firearm and other inputs and costs associated with intelligence in SENAPA and IGGR was difficult to be obtained because of security purposes.

Table 6: Other wildlife law enforcement inputs

Input	SENAPA	IGGR	IWMA
		Mean number	
GPS	53	14	1
Night vision goggle	11	5	-
Uniforms	-	-	-
Radio-calls	97	52	-
Camera	-	17	-
Binoculars	63	26	-
Tents	168	18	3

Source: Annual reports of SENAPA, IGGR and IWMA

4.2.2 Wildlife law enforcement outputs

4.2.2.1 Poachers' arrested

The direct output obtained as a result of anti-poaching operations is apprehension of poachers. Table 7 shows number of poachers arrested per annum per districts from year 2007/08 to 2011/12. Results show annual mean of 28.9 %, 55.4 % and 87.6 % of poachers arrested from SENAPA, IGGR and IWMA respectively were residence of Serengeti district. Other arrested poachers from SENAPA were from districts of Tarime (25.3%), Bariadi (24.6%), Bunda (7.9%), Meatu (5.5%), Magu (5.0%), Shinyanga (2.8%) and Ngorongoro (0.7%). Likewise, IGGR and IWMA reports annual mean arresting of 43.6% and 11.2% from Bunda District respectively and 2.5% and 3.7% from Tarime District respectively. Thus, makes Serengeti the mostly dominant district with higher number of poachers in all DMUs.

Plate 1: Poachers arrested on 3rd December 2012 with snares and bows at Ikorongo/ Grumeti Game Reserves

Plate 2: Park rangers on anti-poaching patrol on 17th December 2012 in Serengeti National Park

Table 7: Number of poachers arrested and their origin

DMU	Year	Districts of origin							
		SERENGETI	BUNDA	BARIADI	TARIME	MAGU	MEATU	NGORONGOR	SHINYANG	TOTAL
SENAPA	2007/2008	391 (37.1)	94 (8.9)	246 (23.4)	274 (26)	21 (2)	17 (1.6)	3 (0.2)	7 (0.7)	1053
	2008/2009	270 (26.3)	121 (11.8)	197 (19.2)	290 (28.2)	83 (8.1)	45 (4.4)	9 (0.9)	13 (1.3)	1028
	2009/2010	297 (29.9)	77 (7.7)	281 (28.2)	157 (15.8)	72 (7.2)	111 (11.2)	-	-	995
	2010/2011	335 (31.8)	76 (7.2)	209 (19.9)	273 (25.9)	41 (3.9)	74 (7)	4 (0.4)	42 (4)	1054
	2011/2012	173 (18.5)	30 (3.2)	312 (33.4)	288 (30.8)	36 (3.9)	30 (3.2)	14 (1.5)	52 (5.6)	935
Mean		293.2 (28.9)	79.6 (7.9)	249 (24.6)	256.4 (25.3)	50.6 (5.0)	55.4 (5.5)	7.5 (0.7)	28.5 (2.8)	1013
IGGR	2007/2008	211 (65.5)	105 (32.6)	-	6 (1.9)	-	-	-	-	322
	2008/2009	267 (56.6)	204 (43.2)	1 (0.2)	-	-	-	-	-	472
	2009/2010	138 (44.8)	170 (55.2)	-	-	-	-	-	-	308
	2010/2011	251 (54.4)	198 (43)	-	12 (2.6)	-	-	-	-	461
	2011/2012	146 (54.7)	121 (45.3)	-	-	-	-	-	-	267
Mean		202.6 (55.4)	159.6 (43.6)	1 (0.3)	9 (2.5)	-	-	-	-	366
IWMA	2007/2008		-	-	-	-	-	-	-	-
	2008/2009		-	-	-	-	-	-	-	-
	2009/2010	48 (92.3)	2 (3.8)	-	2 (3.8)	-	-	-	-	52
	2010/2011	54 (88.5)	7 (11.5)	-	-	-	-	-	-	61
	2011/2012	39 (81.3)	9 (18.8)	-	-	-	-	-	-	48
Mean		47 (87.6)	6 (11.2)	-	2 (3.7)	-	-	-	-	53.7

In brackets are percentages

Source: Anti-poaching records of SENAPA, IGGR and IWMA

Monthly-wise, Fig. 3 shows a decreasing trend in number of poachers arrested from January 2010 to December 2012 in all DMUs. Hilborn *et al.* (2006) argued that poaching varied with law enforcement effort. The trend may be interpreted as result of effective wildlife law enforcement. However, the observed trend cannot justifies decrease in poaching regardless of wildlife law enforcement exercised inside and outside the protected area, it could be due to argument raised by Knapp (2012) who point out that on average poacher has a 0.07% chance of getting caught in Serengeti National park; Implying that, probability of poachers to succeed his/her poaching mission is higher without caught/arrested. Concomitantly, other poaching indicators like number of confiscated weapons and number of wildlife killed/poached (Table 8) does not give clear picture of decreasing poaching. A recent study in the adjoining Masai-Mara Game Reserve of Kenya by Ogutu *et al.* (2009) discovered that many of the key ungulate populations had decreased significantly, a trend which was attributed largely to poaching pressure. Unless the rewards poachers face are significantly greater than the financial, physical, or psychological risks involved, it is unlikely that the level of poaching in Serengeti ecosystem will decrease appreciably (Knapp, 2012).

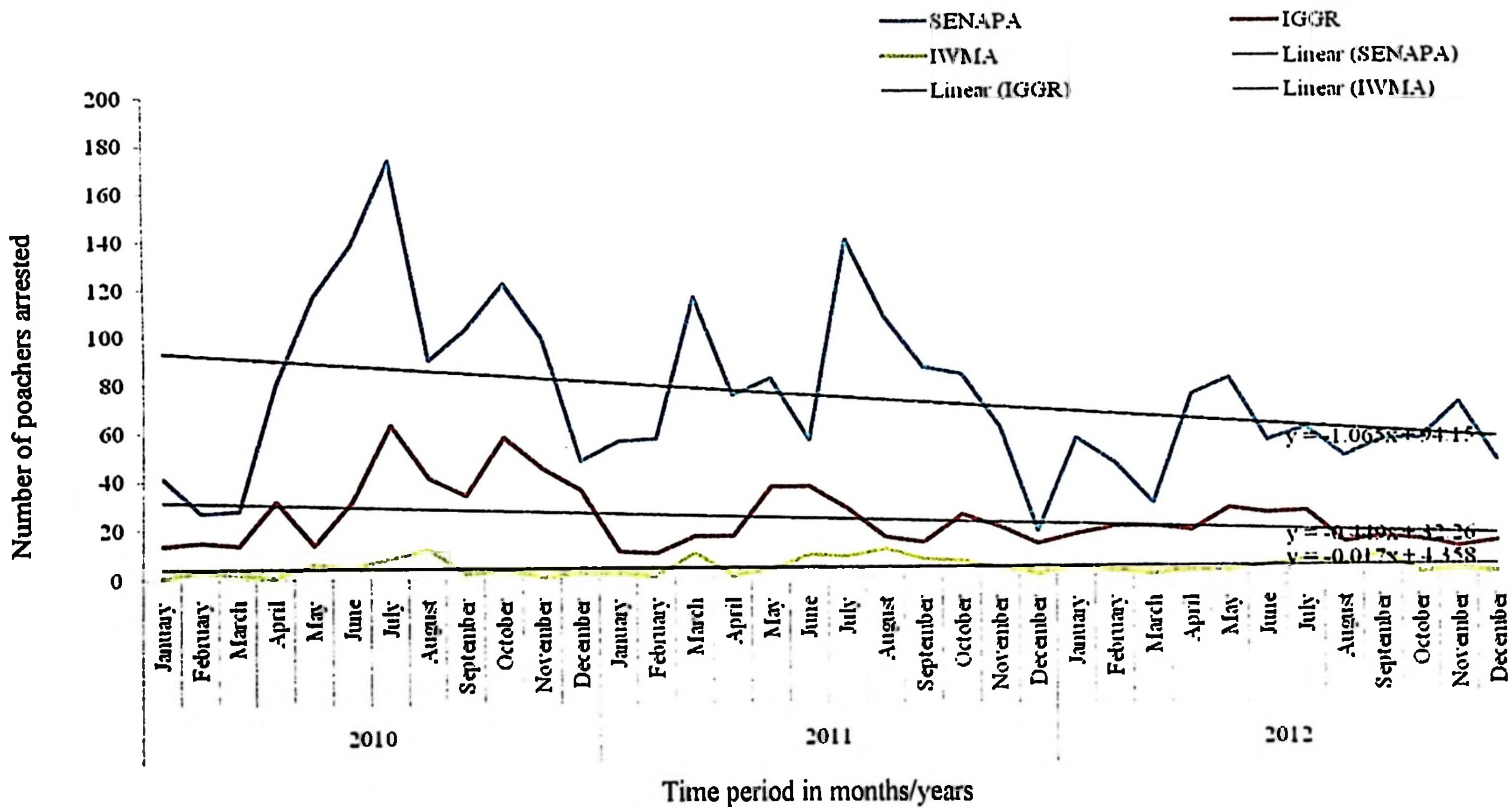

Figure 3: Monthly trend of poachers arrested in three DMUs (2010-2012)

On average number of poachers arrested per month ranges from 18 to 174 in SENAPA, 10 to 63 in IGGR and 1 to 12 in IWMA. High number of arrested poachers occurs from May to September; this being due to high opportunity of poaching resulted by wide scattering of wildlife migration outside the PA where it is reported to have a low level of protection (Rentsch, 2011). It is important to note that the DMU differ considerably in terms of size. Consequently, the nature and volume of poaching also varies from DMU to DMU. Though the etiology of criminality in the protected areas has not been investigated thoroughly but it is clear that differences may be attributed to the DMUs resource use and allocation.

Alongside poachers' arrest weapons were confiscated (Table 8). By far the most dominant form of poaching is through wire snares mostly trapped in the night. In SENAPA and IGGR wire snares confiscated for five years constitute 98% and 81% respectively of the total weapons confiscated. With an abundance of migratory wildlife in the Serengeti ecosystem, wire snares prove an efficient and indiscriminate tool for hunting (Rentsch, 2011). Other weapons are arrows, spears, bows, Firearm/ammunitions, machetes, knives, and motorcycles which were reported to be a serious growing poaching technique (Rwegasira, M. and Msumi, S. personal communication, 2012). Hunters also use pit traps, dogs, spotlighting, to hunt silently (Knapp, 2012). However, confiscation of firearm and ammunitions in SENAPA (0.2% of the total weapons confiscated for five years) indicates serious sophisticated form of poaching.

Table 8: Number of wildlife poached and weapons confiscated by DMUs

Years		2007/ 2008	2008/ 2009	2009/ 2010	2010/ 2011	2011/ 2012
DMU	Wildlife killed/poached					
SENAPA		2711	1740	2690	6453	2728
IGGR		395	278	406	216	213
IWMA		-	-	-	43	30
	Confiscated weapons					
SENAPA		138 427	91 447	192 465	441 521	109 191
IGGR		2019	1571	2792	2346	848
IWMA		-	-	-	78	42

4.2.2.2 Wildlife cases cleared

The cases clearance rate is indicative measure of law enforcement performance (Nagesh, 2006). Clearance of wildlife cases in the court among other things depends on effort of prosecution and attendance level of law enforcement staff as a witnesses and/or evidences as a response of court summons. Table 9 shows that cases cleared per month ranged from 4 to 42 in SENAPA, with 58% monthly rate of conviction[15] and 0 to 13 in IGGR with 33% monthly rate of conviction. Level of cases cleared from IGGR and SENAPA was noted to be 63% and 52% of the total cases received to the courts respectively. Higher level of cases cleared from IGGR is contributed by higher rate of un-conviction (67%) than 42% in SENAPA.

Table 9: Mean number of cases submitted and cleared to court

DMU		Mean number	Std dev	Min	Max
SENAPA	Cases sent to court	33	16.8	11	83
	Cases cleared	17 (52)	9.1	4	42
	Convicted offenders	19 (58)	9.9	4	44
	Un-convicted offenders	14 (42)	15.7	0	71
IGGR	Cases sent to court	8	5.1	1	24
	Cases cleared	5 (63)	3.7	0	13
	Convicted offenders	3 (33)	2.6	0	12
	Un-convicted offenders	6 (67)	6.9	0	24

In brackets are percentages.

[15] The judgment of a jury or judge that a person is guilty of a crime as charged. Conviction include imprisonment and/or fines

SENAPA had higher number of cases sent to the court of which 52% of the cases were convicted. The higher number of SENAPA cases cleared was partly attributed to the effectiveness in handling of cases when reaches police stations. Other reason reported was a good attendance of the SENAPA's law enforcement staff to come up with evidences and/or witnesses evidences before the court of law (Kiswaga, F. Personal communication, 2012).

Relatively, the attendance of IGGR wardens to the court to provide evidences before the court of law was unsatisfactory. Possible reasons identified were; first little allowance of TZS 5 000 paid was reported to be unsatisfactory compared to TZS 60 000 paid to SENAPA staff. Secondly, sometimes there was no transport for the one required to attend the case at the court; Thirdly, the penalties charged to the criminal was reported to be very law hence discourage staff to attend the cases and fourth was late arrival of/not getting court summons. The ultimate results of their absence is dismissal/withdraw of cases with respect to section 225 (a) of Criminal procedure Act (URT, 2002). Together with unsatisfactory attendance of wardens to the court of law, absence of effective handling of cases from police to the court gives room for corruption (Ngowi, 2011); hence cause distortion of many cases. As argued by Ngowi (2011), other reasons for un-conviction are unqualified investigators, poor presentation of proper exhibits and other evidential documents, unmotivated investigators, delayed investigation and absence of Wildlife professional prosecutors.

4.3 Wildlife Law Enforcement Costs

Table 10 shows mothly estimate of costs incured for the wildlife law enforcement were TZS 202 743 311, TZS 78 732 227 and TZS 5 541 928 in SENAPA, IGGR and IWMA respectively. Of the total cost incured 74%, and 65.9% were for personal emolument (salaries) for the law enforcement staff, 12.6% and 15.6% were fuel cost, 9.7% and 12.2% were maintanance of the patrol vehicle and meal costs were 1.9% and 6.2% in SENAPA and IGGR respectively. About 2.8% of the costs were used by SENAPA to attend cases while IGGR used 0.1%. In IWMA, fuel costs constitutes larger portion (42.7%) of the total costs, followed by salaries (33.2%) and vehicles maintanace. No costs was incured to attend cases from IWMA.

Table 10: Real costs of wildlife law enforcement inputs; Monthly mean estimates

DMU	Input costs	Mean Total costs (TZS)	Mean unit cost (TZS)	MIN (TZS)	MAX (TZS)
SENAPA	WLES salary	150 044 230 (74)	514 927.77	309 692.1	1 584 339
	Meal costs	4 021 615 (1.9)	1 327.292	1097.368	1 530.52
	Maintance cost	19 598 524 (9.7)	604 736.962	109 850.2	1 565 170
	Fuel costs	25 484 710 (12.6)	1 778.962	1 577.379	2 089.523
	Allowance to witnesses	1 913 059 (1.0)	52 032.98	43 019.42	60 000
	Allowance to prosecutor	1 681 173 (0.8)	52 032.98	43 019.42	60 000
	Total	202 743 311	1 226 837	508 256	3 273 129
IGGR	WLES salary	51 883 726 (65.9)	387 192	179 246.573	5 692 106
	Meal costs	4 905 495 (6.2)	1 354.253	1 119.658	1 561.609
	Maintance cost	9 621 029 (12.2)	1 069 003	0	3 357 943
	Fuel costs	12 276 619 (15.6)	1 778.962	1 577.379	2089.523
	Allowance to witnesses	45 357.61 (0.1)	4 336.082	3 584.951	5 000
	Allowance to prosecutor	-	-	-	-
	Total	78 732 227	1 463 664	185,529	9 058 700
IWMA	WLES salary	1 837 299 (33.2)	79 882.56	77 904	172 115
	Meal costs	239 772.5 (4.3)	953.4421	788.28	1099.28
	Maintance cost	1 098 788 (19.8)	937 038.1	0	5 412 227
	Fuel costs	2 366 068 (42.7)	1,778.962	1 577.379	2 089.523
	Allowance to witnesses	-	-	-	-
	Allowance to prosecutor	-	-	-	-
	Total	5 541 928	1 019 653	80 270	5 587 531

Personal emolument, fuel and vehicle maintanance account a higher proportion of costs in law enforcement in SENAPA, IGGR and IWMA. High costs of fuel corresponds to vehicle consuption in which together with maintanace costs were influenced by the nature of the patrol area e.g. soil type especially durring rain seasons (loam and muddy), fuel consuptions and maintanaces become higher results to higher costs (Kitutu[16], A. Personnal communication, 2012). Accordingly, type and age of the vehicle may also contribute to higher fuel consuption and frequently maintanances. For example it was stated that Landcruisers Toyota-pick ups which constitutes about 75% , 88.9% and 100% of the anti-poaching patrol vehicles in SENAPA, IGGR and IWMA respectively were not very much efficient in patrolling during rain seasons and therefore consumes more fuel than during dry seasons. While the use of Landrover TDI 110 were appreciated as best all-weather patrolling vehicles with less fuel consuption and less mantained, the new seven (7) bought Landrover TDVI – PUMA in SENAPA were noted with serious and complicated maintanances, *i.e* high maintanace costs (Kitutu, A. Personnal communication, 2012).

4.4 Efficiency scores for SENAPA, IGGR and IWMA

4.4.1 Variable returns to scale assumption

Table 11 shows that wildlife law enforcement in all DMUs was technically efficient. The mean allocative efficiency in SENAPA, IGGR and IWMA was found to be 78.5%, 87.9% and 97.3% respectively as appeared under economic or cost efficiency model. The Allocative efficiency results imply less ability of selecting the correct mix of inputs prevailed in SENAPA compared to IGGR and IWMA. This could probably be due to the fact that SENAPA supplies relatively many law enforcement inputs resources than IGGR and IWMA. Allocative and economic efficiency scores suggest that the inefficiencies were largely contributed by inability of the DMUs to allocate its inputs optimally. Relatively high economic efficiency scores under VRS imply that wildlife law enforcement were less inefficiency in IWMA compared to IGGR and SENAPA. This could be due to the sense of ownership and responsibility developed by surrounding

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[16] *He is a workshop manager of Serengeti National Park*

communities in management of their natural resources which results to decreasing poaching to their own property (WMA) and hence decreasing resource use in law enforcement by management. Participatory wildlife management intends to empower and create involving communities ownership in the process of wildlife conservation (Songorwa, 1999). It aimed at enhancing cooperation between communities and the respective governments in management of wildlife, and promoting sharing of benefits arising from the sustainable management and utilization of wildlife (IIED, 1994).

Table 11: Efficiency scores of SENAPA, IGGR and IWMA – Summary[17]

DMU	Variable (model)	Mean	Min	Max
SENAPA	TE (CRS)	0.689(0.229)	0.248	1.000
	TE (VRS)	1.000(0.000)	1.000	1.000
	AE (CRS)	0.749(0.152)	0.413	1.000
	AE (VRS)	0.785(0.126)	0.627	1.000
	CE (CRS)	0.519(0.222)	0.171	1.000
	CE (VRS)	0.785(0.126)	0.627	1.000
	SE	0.689(0.229)	0.248	1.000
IGGR	TE (CRS)	0.745(0.261)	0.258	1.000
	TE (VRS)	1.000(0.000)	1.000	1.000
	AE (CRS)	0.726(0.19)	0.377	1.000
	AE (VRS)	0.879(0.084)	0.718	1.000
	CE (CRS)	0.545(0.263)	0.192	1.000
	CE (VRS)	0.879(0.084)	0.718	1.000
	SE	0.745(0.261)	0.258	1.000
IWMA	TE (CRS)	0.325(0.261)	0.083	1.000
	TE (VRS)	1.000(0.000)	1.000	1.000
	AE (CRS)	0.966(0.03)	0.869	1.000
	AE (VRS)	0.973(0.03)	0.858	1.000
	CE (CRS)	0.317(0.259)	0.076	1.000
	CE (VRS)	0.973(0.03)	0.858	1.000
	SE	0.325(0.261)	0.083	1.000

Key; TE (VRS) = Technical Efficiency under Variable Return to Scale, TE (CRS) = Technical Efficiency under Constant Return to Scale, AE (VRS) = Allocative Efficiency under Variable Return to Scale, AE (CRS) = Allocative Efficiency under Constant Return to Scale, CE (VRS) = Cost Efficiency under Variable Return to Scale, CE (CRS) = Cost Efficiency under Constant Return to Scale, SE = Scale Efficiency. Numbers in parenthesis are Standard Deviations

[17] *For the detail of monthly efficiencies see Appendix 3*

Higher scores of technical efficiency than that of allocative efficiency and overall efficiency observed suggest that the DMUs have considerable scope to improve the allocative efficiency and economic efficiency. Thus, by improving the allocative efficiency of wildlife law enforcement it can reduce the law enforcement input costs by about 21.5% (SENAPA), 12.1% (IGGR) and 2.7% (IWMA) without reducing output.

4.4.2 Constant returns to scale assumption

Table 11 indicates that the quantitative efficiency analysis revealed a mean technical efficiency of about 74.5%, 68.9% and 32.5% in IGGR, SENAPA and IWMA respectively. To improve their efficiency, proportionately reduction of the input is inevitable (since we run an input-oriented model). Thus, IGGR, SENAPA and IWMA input usage need to radial decrease by 25.5%, 31.1% and 67.5% respectively to be on technical frontier. The mean allocative efficiency was 74.9%, 72.6% and 96.6% in SENAPA, IGGR, and IWMA. Implying that IWMA had relatively higher capacity in selecting the correct mix of inputs quantities to ensure that input price ratios equal the ratios of corresponding marginal output. The result suggests that DMUs experience excess usage of wildlife law enforcement inputs resources in arresting poachers and cases clearing. Thus, allocative efficiency could be improved by decreasing the inputs usage or increasing number of poachers arrested and wildlife cases cleared. Since we run an input-oriented model, results implies that there is scope of decreasing input by 25.1%, 27.4% and 3.4% in SENAPA, IGGR and IWMA respectively if suitably reallocating law enforcement inputs can be practiced. On average, overall economic or cost efficiency in SENAPA, IGGR and IWMA was 51.9%, 54.5% and 31.7% respectively. This concludes that based on CCR model assumption, wildlife law enforcement in all DMUs were economically inefficient, with IWMA being relatively more inefficient followed by

SENAPA and IGGR. Relatively dispersion of observation points used in detections of poaching in IGGR can be argued as the reason for less inefficient in law enforcement since its operation results to saving of anti-poaching input.

Less efficient law enforcement in IWMA could be due to un-proportional number of poachers arrested (as output) to input resources deployed as compared to SENAPA and IGGR. In other words, number of arrested poachers reported was proportionally less compared to wildlife law enforcement inputs usage. To this regard, inefficient wildlife law enforcement scores in IWMA does not contradict with the importance of participatory approach in minimizing wildlife law enforcement inputs, but was due to poor law enforcement outputs database from management of IWMA. For example, most of non-trophy poachers in IWMA who were submitted to village authorities for punishment were not recorded (i.e. not available). Similarly, due to several joint patrols with IGGR law enforcement staff, even some of the trophy poachers were to be handled by IGGR staff and recorded to their database. Probably this could also be an argument for observed relatively efficient wildlife law enforcement in IGGR.

Wildlife law enforcement efficiencies scores of the sampled DMUs under CRS assumption were less than the corresponding VRS efficiencies scores (Table 11). Differences were the result of different scale efficiencies obtained (Carrington *et al.*, 1997; Drake and Simper, 2000; Abdallah, 2006; Sezen and Gok, 2011). Scale efficiency scores of 32.5%, 68.9% and 74.5% of IWMA, SENAPA and IGGR respectively indicate increasing return to scale (IRS) for the majority of observations in each DMU. IRS implies that, increase in wildlife law enforcement inputs would increase number of poachers arrested and cases solving in each DMU un-proportionally or in un-optimal scale. It also suggests that the size of the DMU does not play a significant role in determining its efficiency (Nagesh, 2006). However, the scale efficiencies scores implying that the effect of outputs (number of poachers arrested and cases cleared) from change in wildlife law enforcement inputs may relatively be smaller in IWMA than SENAPA and relatively higher to IGGR. That means SENAPA and IGGR could benefit by optimally input usages with the same output levels.

To overcome scale inefficiency, adapting the new technologies or new service delivery processes and good participatory management practice among other things is recommended (Ozcan, 2008). Community participation in management of wildlife may be used to enhance the understanding and agreement of cost sharing (both financial and physical contribution). Furthermore, community participation can be used to prevent conflicts and to stimulate cooperation and agreement between different actors. In this way illegal extraction of natural resources can be reduced and overall costs minimized (Søren, 2002; Subash, 2010). As argued by proponents of Community Wildlife Management (CWM) this approach is a crucial step because it restores a sense of ownership and responsibility for the resource among community members (IIED, 1994). Putnan (1993) suggests that involving people and communities in decisions and in running local services can make government more efficient.

4.4.3 Super efficiency evaluation – technical efficiency

Table 12 indicate super-efficiency score of SENAPA, IGGR and IWMA were 108.56%, 139.76% and 100.14% respectively, implying that wildlife law enforcement in SENAPA were more technically efficient than IGGR and IWMA. Thus, generally we conclude by ranking every DMU relatively to its peer in the sample.

Table 12: Super-efficiency scores for technical efficient wildlife law enforcement

DMU	Monthly Mean TE (%)	StDev	Min (%)	Max (%)
SENAPA	108.56	16.02	100	172.92
IGGR	139.76	151.11	100	922.4
IWMA	100.14	0.49	100	102.27

From the general ranking of DMUs (Table 13), economic inefficiency of wildlife law enforcement was relatively attributed by its allocative inefficiency than technical efficiency under VRS. This suggests that DMU needs to direct their efforts to impart more knowledge to wildlife law enforcement actors on how best they can select the correct mix of wildlife law enforcement inputs quantities to ensure that input price ratios equal the ratios of corresponding marginal output than proportional decrease of input quantities. On other side overall inefficiency of wildlife law enforcement was relatively attributed by technical inefficiency than allocative inefficiency in optimal scale assumption, suggesting that DMU needs to concentrate more on proportional decrease in wildlife law enforcement inputs than bothering on how best they can allocate them appropriately.

Table 13: Ranking of DMU

DMU	TE (CRS)	TE (VRS)	AE (CRS)	AE (VRS)	CE (CRS)	CE (VRS)	SE
SENAPA	2	2	2	3	2	3	2
IGGR	1	1	3	2	1	2	1
IWMA	3	3	1	1	3	1	3

Key; 1=relatively efficient, 2=less efficient, 3=relatively less efficient.

Economic efficiency of wildlife law enforcement in all DMUs was found inefficient. These results are consistent with Sebahatin and Sinan (2010) who suggest that, law enforcement may not always achieve maximum efficiency, due to the fact that its outputs may not always be measurable or visible for some of its tasks. The phenomenon is evident in wildlife law enforcement operations where sometimes, wildlife law enforcement staff and other inputs perform invisible/indeterminate tasks, such as responding to problem animal control or conducting proactive conservation tasks like community-oriented programs. These tasks cannot be evaluated in terms of efficiency because they do not produce concrete (or countable) outputs (Sebahatin and Sinan, 2010).

Moreover, not all wildlife law enforcement inputs at DMUs directly deals with law enforcement activities at a time, rather there were other obligations to attend. For example, only 62 percent of wildlife law enforcement staff in SENAPA was directly engaged in arresting poachers and clearing of cases per month, likewise to IGGR (40%) and IWMA (26%). Other wildlife law enforcement staff was to perform administrative work, and others were tasked to watch protected area resources such as offices, entrance and exit gates, and air strips. Others were safeguarding tourist hotels, lodges and campsites. Thus, while 48% (SENAPA), 60% (IGGR) and 74% (IWMA) of the manpower were used for mentioned purposes, these activities do not include output variables, such as arresting poachers or solving wildlife cases. Some scouts/rangers also work in intelligence system framework and secure wildlife inside and outside the protected areas. Accordingly, these activities and its successes were not counted in an analysis of efficiency through DEA, even though the total number of law enforcement staff and equipments were considered as an input.

Lockwood *et al.* (2006) highlighted that, decisions made by managers has significant contribution to effectiveness and efficient resource management. In the light of budgets constraints, protected area managers are regularly required to make decisions on how best can allocate their resources or management interventions strategies to employ in order to achieve efficient operations, including wildlife law enforcement. However, to attain a rational and well informed decision is a general world challenge and critical to developing countries (Davey, 1998). In almost all decision situations information is incomplete, whether because there is insufficient time to gather all the available data or it is too costly or simply does not exist. Accordingly, perception of situations, alternatives, consequences and weightings are quite differently across and along management levels/actors of law enforcement chain. As well as personal biases, factors and issues associated with group decision may also create complexity in management of resources. For example while in IGGR and SENAPA some of the decision on use and allocation of input resources are centralized to Wildlife division and National parks headquarters respectively, in IWMA most of decisions including allocation of resources and use of inputs in wildlife law enforcement are centralized to group of WMA village's representatives. Group can either have a negative influence as in increasing goal conflict or can improve rationality through enhancing the quantity of decision alternatives (Lockwood *et al.*, 2006). These may be the explanations for the DEA analysis' findings of inefficiency in studied DMUs.

4.5 Efficiency Improvement

4.5.1 Slack evaluation and target input/output

Wildlife law enforcement inputs and outputs were evaluated based on their average slack values. The target column (Table 14) shows the levels of inputs and outputs that an inefficient DMU should be using or producing in order to be efficient, while the potential improvement column shows how much, in percentage terms, an inefficient DMU use of inputs or output needs to change in order for it to be efficient. To calculate the target values for inputs, the input value were multiplied with an optimal efficiency score and then slack amounts were subtracted from this amount. Likewise, targets outputs were the result of respective slack values added to outputs (Ozcan, 2008).

Table 14: Potential improvements of inputs and outputs to target level

DMU	Input/ output	Mean input/ output	Mean Technical Efficiency		Mean slacks value		Target input/output		Potential improvement (%)	
			CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
SENAPA										
	WLES	291	0.689	1.000	24	20	177	271	39.18	6.87
	RTN	3029	0.689	1.000	212	0	1875	3029	38.1	0
	VH	34	0.689	1.000	5	5	18	29	47.1	14.7
	FUEL	14294	0.689	1.000	2186	2025	7663	12269	46.4	14.2
	FW	36	0.689	1.000	2	5	23	31	36.1	13.9
	FP	33	0.689	1.000	3	2	20	31	39.4	6.1
	POA	74	0.689	1.000	2	9	53	83	28.4	-12.2
	CC	17	0.689	1.000	0	1	12	18	29.4	-5.9
IGGR	WLES	134	0.745	1.000	7	2	93	132	30.72	1.49
	RTN	3624	0.745	1.000	178	64	2522	3560	30.41	1.77
	VH	9	0.745	1.000	0	0	7	9	25.5	0
	FUEL	6869	0.745	1.000	979	559	4138	6310	39.75	8.14
	FW	10	0.745	1.000	1	2	6	8	35.5	20
	FP	11	0.745	1.000	1	0	7	11	34.59	0
	POA	24	0.745	1.000	0	1	18	23	25.5	4.17
	CC	5	0.745	1.000	0	1	4	4	25.5	20
IWMA	WLES	23	0.348	1.000	0	0	8	23	65.2	0
	RTN	298	0.348	1.000	2	18	102	280	65.8	6.0
	VH	2	0.348	1.000	0	0	1	2	50	0
	FUEL	1184	0.348	1.000	6	72	406	1112	65.7	6.1
	POA	4	0.348	1.000	0	1	1	5	75	-25

Key: BCC- Benker, Charnes and Cooper Model, CCR-Charnes, Cooper and Rhodes Model, WLES-Wildlife Law Enforcement Staff, RTN – Ration/Meal, FW- Frequency of WLES to court witness, FP-Frequency of wildlife cases prosecution, POA- Poachers arrested, and CC- wildlife cases cleared.

Results revealed higher difference between the observed inputs to corresponding target inputs under CCR model assumptions relatively to BCC model assumptions. This implies that DMUs needs to reduce more inputs under CCR than BCC model assumption. For example SENAPA requires to reduce monthly fuel consumption by 6631litres (46.4%) under CCR model assumptions while under BCC model assumption requires to reduce fuel by 2025 litres (14.2 %). Likewise, IGGR require reducing number of wildlife law enforcement by 31.34% and 1.49% under CCR and BCC model assumption respectively (Appendix 5) and IWMA needs to decrease number of vehicles used to execute law enforcement by 50% and 0% under CCR and BCC model assumption respectively. Higher difference between the observed and target inputs/outputs under CCR model were due to optimality scale assumed in input-output relationships. Thus, wildlife law enforcement inputs applied are too higher (un-optimal) to number of poachers arrested and cases cleared. However, less difference between observed and target inputs under BCC model assumptions were the result of only slack removal after zero radial decrease. Information on target levels and potential improvement can be used to provide the DMU with important suggestions for improving the performance of their inefficient units. Another way to achieve higher efficiency is to introduce technological changes, or to reengineer service processes "lean management" which in turn may reduce inputs or ability to produce more outputs (Ozcan, 2008).

4.6 Socio-Economic Factors for Inefficiencies in the Wildlife Law Enforcement

4.6.1 Characteristics of wildlife law enforcement staff

Law enforcement staff interviewed comprised of males and females, with different ages, education background and work experience (Table 15). Of the total law enforcement staff interviewed, 47.9%, 67.9% and 50% from SENAPA, IGGR and IWMA respectively were ranging from 20-35 years. This implies that large work force in executing wildlife law enforcement was relatively comprised by youth than middle class age and high age class. However, the results alarms SENAPA to recruits more wildlife law enforcement staff within the coming ten years to replace the coming retirement of 38% of the staff who were above 46 years of age.

Table 15: Descriptive results of socio-economic characteristics of respondents

Information	SENAPA N= 71	IGGR N= 53	IWMA N= 18
(a) Age class			
20- 35 years	34 (47.9)	36 (67.9)	9 (50)
36- 45 years	10 (14.1)	13 (24.5)	7 (38.9)
≥ 46years	27 (38.0)	4 (7.5)	2 (11.1)
(b) Sex			
Male	69 (97.1)	52 (98.1)	17 (94.4)
Female	2 (2.8)	1 (1.9)	1 (5.6)
(c) Education background			
Primary education	28 (39.4)	42 (79.2)	17 (94.4)
Secondary education	37 (52.1)	7 (13.2)	0 (0)
College/University education	6 (8.5)	4 (7.6)	1 (5.6)
(d) Experience			
1-10 years	36 (50.7)	47 (88.7)	15 (83.3)
11- 20 years	16 (22.5)	1 (1.9)	2 (11.1)
21 – 30 years	17 (23.9)	1 (1.9)	1 (5.6)
≥ 31 years	2 (2.8)	4 (7.5)	0
Others	Monthly mean	Monthly mean	Monthly mean
Incentives (TZS)	239 302	75 809	0
Rest-days (days)	3	8	15
Labour (patrol man-days)	3283	1281	165

In brackets are percentages

Education background of the sampled wildlife law enforcement staff were mainly secondary education (52.1%) in SENAPA and primary education in IGGR (79.2%) and IWMA (94.4%). The differences were due to the current qualification requirements in recruitment. While SENAPA recruits their staff with minimum secondary education, Grumeti Tourist Company who her game scouts contribute about 85.8% of the total law enforcement staff of IGGR recruits their scouts based on their physical fitness. Thus, qualifications of employment were based on successful completion of settled physical exercises followed by sub-military training. Similar to IWMA, employed game scouts must come from communities around IGGR and IWMA with minimum qualification of primary education, in which majority of villagers qualifies (Ngowe, 2003). Of the total wildlife law enforcement staff interviewed 50.7%, 88.7% and 83.3%

in SENAPA, IGGR and IWMA respectively had less than 10 years working experience in wildlife law enforcement field.

4.6.2 Challenges of wildlife law enforcement

Inadequate resource was the main concern to most of wildlife law enforcement staff, as summarized in Table 16. The most important challenge for wildlife law enforcement as portrayed by more than half of respondents, in all DMUs were inadequate firearms, less salary for game scouts, inadequate transport for patrols and poor infrastructure especially during rain seasons. The results were consistent to the findings of Ford (2005) who concludes that effectiveness and efficiency of anti-poaching activities in community conservation project-MBOMIPA (*Matumizi Bora ya Malihai Idodi na Pawaga*) were impaired by inadequate equipments and game scouts. Fundamental improvements such as these will have the most dramatic outcome on efficient patrols, and wildlife law enforcement at large. Other identified challenges were varied from one DMU to another.

Table 16: Frequencies of challenges of wildlife law enforcement in three DMUs

Challenges	DMU		
	SENAPA N= 71	IGGR N= 53	IWMA N= 18
Low salaries	47 (66.2)	34 (64.2)	14 (77.8)
Training for game scouts	4 (5.6)	15 (28.3)	5 (27.8)
Inadequate patrol vehicles	50 (70.4)	27 (50.9)	9 (50.0)
Inadequate firearm	61 (85.9)	47(88.7)	17 (94.4)
Inadequate patrol gears[18]	23(32.4)	0 (0.0)	12 (66.7)
Inadequate ranger posts	45 (63.4)	7 (13.2)	9 (50.0)
Inadequate personnel	38 (53.5)	7 (13.2)	4 (22.2)
Inadequate radio calls	5 (7.0)	1 (1.9)	6 (33.3)
Provision of off-days	49 (69.0)	2 (3.8)	2 (11.1)
Lack of IDs	0 (0.0)	1 (1.9)	13 (72.2)
Poor infrastructure especially during rain seasons	39 (54.9)	35 (66.0)	11 (61.1)

In brackets are percentages

[18] *Patrol gears includes uniform, GPS, camera, night-goggle vision, binoculars and tents*

Table 16 shows that off-days to wildlife law enforcement staff of SENAPA were critical challenge compared to IWMA and IGGR. However, Table 15 shows that, the mean numbers of days offered per person per month for resting were 3, 8 and 15days in SENAPA, IGGR and IWMA respectively. Estimation of rest days took into account annual leave of 28 days offered to personnel of SENAPA and Game officers/wardens of IGGR. It also considered monthly days-off of 9 and 15 days offered to game scouts of Grumeti Tourist Company and Ikona wildlife management area in that order. A day was estimated to correspond 8 to 12hrs working hours. Since it was rare for law enforcement operations to be done at night, night hours were not included in estimation.

It was noted that anti-poaching patrols in all DMUs is done on daily basis, though the number of law enforcement staff sometimes differ due to other activities/tasks. Table 17 shows that, the monthly mean labour deployed were 3283, 1281 and 165 patrol man-days in SENAPA, IGGR and IWMA correspondingly. Therefore, monthly mean number of law enforcement staff participating in anti-poaching patrols was 109, 43, and 6 in SENAPA, IGGR and IWMA, equivalent to law enforcement staff to patrol area ratio of 1:135 km^2, 1:88 km^2 and 1:40 km^2 respectively. From the recommendation of IUCN of one ranger/scouts to patrol an area of 25 km^2, the results justifies that all DMUs had a shortage of law enforcement staff with critical to SENAPA followed by IGGR and IWMA. Higher challenge to SENAPA was also supported by 53.5% of the respondents (Table 19) which is attributed by the size of the patrol area.

It was also observed that wildlife law enforcement staff of SENAPA and IGGR receives monthly rewards/bonuses for the aim of motivating them and increase their efficiency to law enforcement operations (Jachmann and Billiouw, 1997). The link between rewards and enforcement operations were also highlighted by Messer (2000) who argues that "regardless of the strictness of wildlife policy or well equipped unit, efforts must be made to keep the law enforcement unit free of corruption''. This can only be done through training and significantly raising the wages and rewards to law enforcement staff which could act as incentive to monitor and protect wildlife. Otherwise, they will create a conflict of interest in the patrolling and eventually becoming poachers themselves.

While salaries were low, rewards were also claimed to be inadequate. Table 15 shows monthly mean of TZS 239 302 and TZS 75 809 were provided to law enforcement staff of SENAPA and IGGR respectively as rewards. The mean rewards provided to SENAPA rangers/wardens were made of rhino protection bonus, TZS 60 000 per patrol-person per month and outpost bonus/allowance per person per month TZS 40 000. Other incentives were reward from apprehending poacher, TZS 10 000 per poacher arrested and snares destroyed reward TZS 1000 per wire destroyed. In IGGR monthly mean rewards of TZS 75 809 was a result of 10% of the salary given to GTC scouts and TZS 10 000 and TZS 6000 per person per patrol-day given to game officers and wardens respectively to motivate their full participation in daily anti-poaching patrols. This incentive mechanism to IGGR was meant to improve anti-poaching effectiveness due to the fact that only game officers and wardens are legally allowed to handle firearm, being few in number and risk anti-poaching patrols requires armed, it was important to set rewards (Seki, A. Personal communication, 2012). However, all mentioned rewards to IGGR were provided by Grumeti Tourist Company.

4.6.3 Factors for inefficiencies in the wildlife law enforcement

To determine whether socio-economic factors influence wildlife law enforcement efficiency, censored regression model were deployed (Equation [8]). Estimated monthly technical inefficiency, allocative inefficiency and cost inefficiency scores for the year

2012 under both model specifications were regressed separately with the corresponding monthly labour (patrol man-days), rest-days (days) and incentives (TZS). Only this variables were used because variation of other socio-economic data like age, experience and education level which were believed to influence efficiency (Msuya, 2003) had to be treated annually and its corresponding possible dependent variable which might be annual estimated efficiency of wildlife law enforcement were few (only three from three DMUs for three years), therefore difficulty to justify any outcome. The reason for using monthly explanatory variables of year 2012, was the difficulties for the respondents to recall the past years information. Rest-days and incentives in IWMA were constant throughout the year, resulting to multicolinearity. Similarly, 100% technical efficiency under BCC model assumptions in all DMUs resulted to unqualified censored dependent variables. The regression results of Table 19, indicates that explanatory variables explain about 1.9% to 45%, and 12.3% to 46 %, of the variation in efficiencies scores under CRS and VRS assumption respectively. Possibly, higher model fitness was to be attained if other socio-economic factors were included in the model.

(a) Rest-days

Table 17 shows that, with BCC model assumption days given for the rangers/wardens to rest (rest-days) had significant influence on allocative efficiency and economic efficiency with similar coefficient of 0.041 in SENAPA at 5% level of significance. Similar influence was also noted on economic efficiency under CCR model (0.262) in IGGR at 10% level of significance. The direction of influence was indicated by the negative sign in all DMUs based on both model specifications. This implies that with BCC and CCR model assumptions, increase in rest time by one day decreases economic or overall efficiency by 4.1% and 26% in SENAPA and IGGR correspondingly. Results on the direction of influence were contrary to our expectations; probably this could be due to the fact that provision of rest-days decreases the labour to perform wildlife law enforcement activities as a result output also decreases. In line with this argument, decrease in labour encourages vehicle intensive patrols leading to higher fuel and maintenance costs. This reduces anti-poaching patrols effectiveness by minimizing probability of detection (Hilborn *et al.*, 2006; Thirgood *et al.*, 2008).

Table 17: Factors for inefficiency of wildlife law enforcement in each DMU

DMU	Variable	Constant Return to Scale			Variable Return to Scale		
		TE	AE	CE	TE	AE	CE
SENAPA	Constant	-0.294	0.94**	0.18	NA	0.834***	0.834***
		(0.7606)	(0.32)	(0.45)		(0.16)	(0.16)
	Labour	0.0003*	-0.00006	0.000075	NA	0.000012	0.000012
		(0.0001)	(0.00005)	(0.000075)		(0.00003)	(0.00003)
	Rest-days	-0.0007	-0.036	-0.026	NA	-0.041**	-0.041**
		(0.06)	(0.026)	(0.037)		(0.015)	(0.015)
	Incentives	5.20e-07	-2.2e-07	2.37e-07	NA	-3.38e-07	-3.38e-07
		(2.21e-6)	(9.66e-07)	(1.37e-06)		(4.91e-07)	(4.91e-07)
	LL- value	-0.907	8.15	4.84	NA	15.7	15.7
	Model Fitness	35%	20%	22%	NA	46%	46%
IGGR	Constant	2.95*	1.77	2.77*	NA	1.358	1.358
		(1.37)	(1.07)	(1.28)		(0.299)	(0.299)
	Labour	0.000021	-0.000071	-0.00012	NA	-0.00015**	-0.00015**
		(0.0003)	(0.00023)	(0.00027)		(0.00007)	(0.00007)
	Rest-days	-0.272	-0.133	-0.262*	NA	-0.392	-0.392
		(0.1579)	(0.123)	(0.147)		(0.033)	(0.033)
	Incentives	2.75e-06	5.35e-07	1.29e-06	NA	1.36e-07	1.36e-07
		(1.9e-06)	(8.71e07)	(1.04e-06)		(2.36e-07)	(2.36e-07)
	LL- value	-3.865	-0.25	-1.79	NA	12.31	12.31
	Model fitness	42%	10%	29%	NA	33%	33%
IWMA	Constant	0.089*	0.731***	0.042	NA	1.12***	1.12***
		(0.965)	(0.206)	(0.764)		(0.13)	(0.13)
	Labour	0.00087	0.001	0.0013	NA	-0.00099	-0.00099
		(0.0058)	(0.001)	(0.0046)		(0.00079)	(0.00079)
	Rest-days	NA	NA	NA	NA	NA	NA
	Incentives	NA	NA	NA	NA	NA	NA
	LL- value	-4.57	8.177	-0.984	NA	16.47	16.47
	Model fitness	2%	7.8%	1.9%	NA	12.3%	12.3%

Key: *, ** and *** represents 10%, 5% and 1% significance level respectively. LL – Log likelihood, in brackets are standard error, NA – not applicable, see definition of TE, AE, CE, in page 57

(b) Labour

With CCR model assumption, Table 17 indicates labour had positive influence on technical efficiency by 0.0003 at significance level of 10% in SENAPA as expected. This result suggests that technical efficiency can be increased by 0.003% as are result of increase in labour by one patrol man-day. In IGGR, labour (0.00015) significantly influences economic efficiency only with BCC model assumptions at 95% confidence. Negative sign suggest that increased in labour decreases economic efficiency. Since, anti-poaching patrols were daily conducted (i.e. no opportunity of increasing days), and labour in this study ware proxied by number of law enforcement staff times patrol-days (man-days), results suggests increasing the number of law enforcement staff to attain technical efficient wildlife law enforcement in SENAPA. On other side, the result suggests not to increase wildlife law enforcement staff in IGGR.

(c) Incentives

Economic efficiency of the wildlife law enforcement in DMUs studied was not influenced by incentives because none of the coefficients of the incentives variable were significant. The findings are inconsistent with that of Ford (2005) who argues that bonuses and rewards paid to wildlife law enforcement staff in MBOMIPA had insignificant influence on the effectiveness and efficiency of wildlife law enforcement. The result suggests that rewards scheme were not acting as an incentives to wildlife law enforcement staff. Therefore, DMU's decision to terminate the reward scheme may be optimum decision in this case, as the resources may be redirected to other needs, such as equipment or wages. Otherwise, rewards schemes should be reviewed so that it can significantly act as incentives and influence the efficiency. The latter suggestion are in line with the responses of interviewer who claims less incentives and some of them they were not been reviewed for long time, For example, rewards obtained from apprehending poachers and destroying of snares in the wild in SENAPA was TZS 10 000 per poacher apprehended and TZS 1000 per wire snare confiscated respectively. These rewards were set fifteen years ago and not reviewed to date.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The preceding analysis attempted to evaluate and compare wildlife law enforcement efficiency in Serengeti National Park, Ikorongo/Grumeti Game Reserves and Ikona Wildlife Management Area with BCC and CCR model assumptions. It also attempts to analyze the possible influencing factors of efficiency variations. Therefore, this study concludes that:

Eight conservation related restrictions were identified. The restrictions were the same in all DMUs; differ in magnitude when it comes to offence. The difference was due to the contradictions stipulated in conservation laws governing the management of wildlife in respective protected areas.

Allocation of wildlife law enforcement inputs and its associate costs were relatively higher in apprehending poachers and less in activities directed to clearance of wildlife cases with critical to IWMA than IGGR and SENAPA.

Wildlife law enforcement in studied DMUs was economically inefficient with relatively more inefficiency under CCR than BCC model assumption. Mean economic efficiency score estimated justifies that with variable returns to scale assumption, wildlife law enforcement in IWMA were less economic inefficient, than IGGR and SENAPA. This may be due to sense of ownership and responsibility developed through community-based wildlife management which resulted to decrease in usage of law enforcement inputs. However, IWMA were found to be more economic inefficient than SENAPA and IGGR with optimal return to scale assumption this may be due to higher unproportionality of input to output relationship resulted from poor recording/database of poachers apprehended.

Provisions of rest-days were observed to influence economic efficiency in SENAPA and IGGR with variable and optimal scale assumptions respectively. Negative coefficients of rest-days variable indicate that provision of rest-days decreases economic efficiencies. Likewise, positive and negative coefficients of labour under optimal and variable scales assumptions in SENAPA and IGGR correspondingly implying that increase in labour results to increase in technical efficiencies to SENAPA and decreases the economic efficiencies in IGGR.

5.2 Recommendations

In this study economic inefficiency of wildlife law enforcement resulted from allocative inefficiency and technical inefficiency with CCR model assumptions, and where technical efficient wildlife law enforcement was observed under BCC model assumption still economic inefficiency was attributed by allocative inefficiency. Therefore, given the empirical findings, the study recommends the following:-

(i) Wildlife conservation laws and related act should be reviewed to remove contradictions in magnitude of offence to the same restriction.

(ii) Increase in allocation of wildlife law enforcement inputs in activities directed to clearance of wildlife cases, including provision of motivation to magistrates and other associates actors in clearance of wildlife cases.

(iii) Provision of knowledge and skills to different actors/decision makers of wildlife law enforcement on proper allocation of wildlife law enforcement inputs is very imperative

(iv) Active participation of local communities in management of wildlife is strongly suggested to SENAPA and IGGR, since it contributes to saving and sharing of law enforcement costs.

(v) Though, DEA findings suggests decrease in number of law enforcement staff, it is worthily to recommend increasing number of law enforcement with twofold reasons; first is the critical poaching pressure reported in Serengeti ecosystem which demands more staff to deal with it and secondly is the multi-task activities which decreases the work force to attend the wildlife law enforcement operations

(vi) With negative influence of rest-days variable to economic efficiency of wildlife law enforcement in SENAPA it is suggested to employ more staff, which can offset the gap of staff who will be given enough time to rest as it is important for the staff to be given time to rest. To IGGR it is recommended to decrease the number of rest-days per month while maintaining labour force.

(vii) Insignificant influence of incentives to efficiencies of wildlife law enforcement suggests review of the rewards schemes so as it can acts as incentives.

5.3 Suggestions for Further Research

This study focused on evaluation and comparisons of economic efficiency of wildlife law enforcement in three DMU. A comprehensive study could be undertaken to compare the efficiency scores of wildlife law enforcement in Serengeti ecosystem protected areas and other ecosystems protected areas in Tanzania. Such comparison of the efficiencies might provide a true picture of wildlife law enforcement efficiencies in protected areas of Tanzania. Future research should also address the effect of administrative leadership on wildlife law enforcement efficiency. It seems likely that good leaders can better guide their organizations toward the efficient use of resources (Sezen and Gok, 2011). Additionally, further research could also investigate in detail the influence of socio-economic and external factors as well as community participation in management of wildlife on efficiency variation.

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APPENDICES

Appendix 1: Wildlife law enforcement inputs and outputs

i. Serengeti National Park (SENAPA)

Year	Month	Inputs: Wildlife Law enforcement Staff SPW	PWI	PW II	SPR	PR I	PR II	PR III	PR IV	Meal ration (RTN) (Kg)	Patrol vehicles (VH)	Fuel (litres)	Frequency to court witness (FW)	Frequency of cases prosecution (FP)	Outputs: POA	WCC
2010	January	4	4	8	3	6	21	6	171	3029.94	18	7105	38	30	41	15
	February	4	4	8	3	6	21	6	171	3029.94	18	8614	46	24	27	6
	March	4	4	8	3	6	21	6	171	3029.94	18	9861	40	32	28	4
	April	4	4	8	3	6	21	7	171	3029.94	18	7935	40	34	80	11
	May	4	4	8	3	6	21	7	177	3029.94	18	7421	30	26	117	13
	June	4	4	8	3	6	21	7	177	3029.94	27	10892	43	26	139	4
	July	4	4	8	3	6	21	9	236	3029.94	27	11001	38	32	174	23
	August	4	4	8	3	6	21	9	236	3029.94	27	10900	34	32	90	8
	September	4	4	8	3	6	21	9	236	3029.94	27	10121	53	34	103	42
	October	4	4	8	3	6	21	9	236	3029.94	37	14982	35	32	122	22
	November	4	4	8	3	7	24	9	232	3029.94	37	15480	28	32	99	34
	December	4	4	8	3	7	24	9	232	3029.94	37	16214	14	35	48	10
2011	January	4	4	8	4	7	24	9	231	3029.94	37	15760	37	28	56	23
	February	4	4	8	4	7	24	9	231	3029.94	37	16054	54	26	57	9
	March	4	4	8	4	7	24	9	231	3029.94	37	15967	57	30	116	33
	April	4	4	8	4	7	24	9	231	3029.94	37	14986	51	34	75	25
	May	4	4	8	4	7	24	9	231	3029.94	37	14119	44	34	82	15
	June	4	4	8	4	7	24	9	231	3029.94	37	16023	49	34	56	20
	July	4	4	8	4	7	24	8	238	3029.94	37	15001	49	32	140	11
	August	4	4	8	4	7	24	8	238	3029.94	37	15980	67	36	107	21
	September	4	4	8	4	7	24	8	238	3029.94	37	14892	42	36	86	8
	October	4	4	8	4	10	37	16	223	3029.94	37	15600	34	40	83	7
	November	4	4	8	4	10	37	16	223	3029.94	37	16093	31	40	61	15
	December	4	4	8	4	10	37	16	223	3029.94	37	14997	20	32	18	8

SENAPA Cont...

		INPUTS													OUTPUTS	
		Wildlife Law enforcement Staff								Meal(Kg)	Patrol vehicles	Fuel (litres)	Frequency to court witness	Frequency of cases prosecution	POA	WCC
Year	Month	SPW	PWI	PW II	SPR	PRI	PR II	PR III	PR IV							
2012	January	4	4	8	4	10	37	16	223	3029.94	37	16082	18	26	56	18
	February	4	4	8	6	10	37	16	223	3029.94	37	15271	37	34	46	17
	March	4	4	8	6	10	37	16	223	3029.94	37	16378	22	34	29	21
	April	4	4	8	6	10	37	16	223	3029.94	37	16929	15	36	74	31
	May	3	4	8	10	10	37	16	210	3029.94	39	15860	17	32	81	18
	June	3	4	8	10	10	37	16	210	3029.94	39	16092	21	34	55	15
	July	3	4	8	10	10	69	21	210	3029.94	39	15921	22	32	60	10
	August	3	4	8	10	10	69	21	210	3029.94	41	18236	43	32	48	31
	September	3	4	8	10	10	69	21	210	3029.94	41	17192	42	40	55	15
	October	3	4	8	10	10	69	21	210	3029.94	41	15666	37	36	55	13
	November	3	4	8	10	10	69	21	210	3029.94	41	17974	38	32	70	19
	December	3	4	8	10	10	69	21	210	3029.94	41	17001	19	30	46	9
	Mean	3.778	4	8	5.167	7.972	33.917	12.25	216.31	3029.94	33.972	14294.4	36.25	32.47222	74.444	16.778
	StDev	0.422	0	0	2.741	1.781	17.089	5.256	21.833	1.38E-12	7.497	3113.698	12.942	3.873	35.414	9.134
	Minimum	3	4	8	3	6	21	6	171	3029.94	18	7105	14	24	18	4
	Maximum	4	4	8	10	10	69	21	238	3029.94	41	18236	67	40	174	42

Key; SPW- Senior park warden, PWI- Park warden I, PWII-Park warden II, SPR- Senior park ranger, PRI- Park ranger I, PRII- Park ranger II, PRIII- Park ranger III, PRIV- Park ranger IV, POA- Poachers arrested, WCC- Wildlife Cases Cleared

ii. Ikorongo/ Grumeti Game Reaserves (IGGR)

		Inputs												Output	
		Wildlife law enforcement staff							Meal/ration (kg)	patrol vehicles	Fuel (litres)	frequency to court witness	Frequency of cases prosecution	POA	WCC
Year	Month	GO	GW	WO	PL	APL	GS	OS							
	January	2	18	3	6	17	68	22	3725.89	9	6365.491	16	6	14	2
	February	2	18	3	6	17	69	21	3365.32	9	4677.587	10	12	15	1
	March	2	18	2	6	17	67	21	3652.11	9	5858.102	14	8	14	1
	April	2	18	2	6	17	67	21	3534.3	9	5099.359	0	10	32	1
	May	2	18	1	6	17	67	21	3652.11	9	5353.836	14	14	14	1
2010	June	2	18	1	6	17	67	21	3534.3	9	5977.286	12	13	32	1
	July	2	18	1	6	17	67	21	3652.11	9	9284.724	14	11	63	5
	August	2	18	1	5	17	66	21	3578.33	9	8765.528	20	6	41	2
	September	2	18	1	5	17	66	21	3462.9	9	6971.17	11	19	34	11
	October	2	18	1	5	17	65	21	3541.44	9	6174.756	17	11	58	5
	November	2	18	1	4	17	66	21	3427.2	9	8015.705	12	7	45	6
	December	2	18	1	5	17	65	21	3541.44	9	9147.602	18	6	36	9
	January	2	18	3	6	17	64	20	3504.55	9	7310.427	7	9	11	11
	February	2	18	3	6	17	61	20	3065.44	9	171.6628	12	16	10	9
	March	2	18	2	6	17	79	22	4131.68	9	8814.498	14	10	17	7
	April	2	18	2	6	17	72	22	3748.5	9	5388.163	8	12	17	5
	May	2	18	3	6	17	77	22	4057.9	9	4950.061	6	14	37	11
2011	June	2	18	3	5	16	75	21	3748.5	9	16586.6	10	9	37	5
	July	2	18	2	5	16	75	21	3873.45	9	5126.846	12	13	28	10
	August	2	18	3	5	16	75	21	3873.45	9	8624.136	18	11	16	3
	September	2	18	3	5	16	75	21	3748.5	9	8592.371	21	20	14	7
	October	2	16	2	5	16	75	21	3799.67	9	5814.802	26	11	25	8
	November	2	16	3	5	16	73	20	3570	9	9293.512	19	14	20	3
	December	2	16	1	5	16	73	20	3689	9	5576.078	4	13	13	2

Key: GO- Game officers, GW- Game warden, WO- Wildlife officer, PL- Patrol leader, APL- Assistant patrol leader, GS- Game scouts, OS- Other staff (it includes drivers, cooks, and turn-boys), POA – Poachers arrested and WCC- Wildlife Cases Cleared

IGGR Cont...

Year	Month	Inputs												Output	
		Wildlife law enforcement staff							Meal/ ration (kg)	patrol vehicles	Fuel (litres)	Frequency to court witness	Frequency of cases prosecution	POA	CC
		GO	GW	WO	PL	APL	GS	OS							
	January	1	16	3	5	16	73	20	3689	9	6871.979	6	9	17	3
	February	2	16	3	5	16	73	20	3451	9	9084.276	7	11	20	13
	March	2	16	3	5	16	73	20	3689	9	4806.801	2	14	20	4
	April	2	13	3	5	16	73	20	3462.9	9	7727.472	5	12	18	2
	May	2	13	3	5	16	73	22	3652.11	9	185.145	0	12	27	4
	June	2	13	3	5	16	73	22	3534.3	9	8246.057	1	16	25	3
	July	2	13	3	5	16	73	24	3725.89	9	8680.358	10	9	26	1
	August	2	13	3	5	16	70	22	3541.44	9	7881.655	4	10	13	9
	September	2	11	3	5	16	70	22	3355.8	9	9361.512	7	11	15	11
	October	2	11	3	5	16	70	26	3615.22	9	9568.836	3	10	14	1
	November	2	13	3	5	16	70	26	3570	9	6931.77	2	6	11	6
	December	1	13	3	5	16	70	26	3689	9	0	1	8	13	5
	Mean	1.944	16.306	2.333	5.306	16.472	70.417	21.5	3623.715	9	6869.06	10.08333	10.7	23.94444	5.222222
	StDev	0.232	2.352	0.862	0.525	0.506	4.136	1.612	194.708	0	3009.901	6.656361	2.7	13.09513	3.641908
	Minimum	1	11	1	4	16	61	20	3065.44	9	0	0	6	10	1
	Maximum	2	18	3	6	17	79	26	4131.68	9	16586.6	26	16	63	13

Key: GO- Game officers, GW- Game warden, WO- Wildlife officer, PL- Patrol leader, APL- Assistant patrol leader, GS- Game scouts, OS- Other staff (it includes drivers, cooks, and turn-boys), POA – Poachers arrested and WCC- Wildlife Cases Cleared

iii. Ikona Wildlife Management Areas (IWMA

Year	Month	Inputs: Wildlife law enforcement staff GO	GS	Meal (Kg)	Patrol vehicles	Fuel (litres)	Output: Poachers arrested
	January	1	22	304.172	2	1100	1
	February	1	22	274.736	2	1100	3
	March	1	22	304.172	2	1100	2
	April	1	22	294.36	2	1100	1
2010	May	1	22	304.172	2	1100	6
	June	1	22	294.36	2	1200	5
	July	1	22	304.172	2	1200	8
	August	1	22	304.172	2	1200	12
	September	1	22	294.36	2	1200	2
	October	1	22	304.172	2	1200	3
	November	1	22	294.36	2	1200	1
	December	1	22	304.172	2	1200	2
	January	1	22	304.172	2	1100	2
	February	1	22	274.736	2	1100	1
	March	1	22	304.172	2	1100	10
	April	1	22	294.36	2	1100	1
	May	1	22	304.172	2	1100	3
	June	1	22	294.36	2	1150	9
2011	July	1	22	304.172	2	1150	8
	August	1	22	304.172	2	1190	11
	September	1	22	294.36	2	1200	7
	October	1	22	304.172	2	1200	6
	November	1	22	294.36	2	1200	3
	December	1	22	304.172	2	1200	1
	January	1	22	304.172	2	1100	3
	February	1	22	274.736	2	1150	2
	March	1	22	304.172	2	1200	1
	April	1	22	294.36	2	1200	2
	May	1	22	304.172	2	1250	2
2012	June	1	22	294.36	2	1200	4
	July	1	22	304.172	2	1200	6
	August	1	22	304.172	2	1200	5
	September	1	22	294.36	2	1200	8
	October	1	22	304.172	2	1250	1
	November	1	22	294.36	2	1500	2
	December	1	22	304.172	2	1500	1
Mean		1	22	298.4483	2	1184.444	4.027778
STD		0	0	8.577988	0	91.63419	3.220347
Min		1	22	274.736	2	1100	1
Max		1	22	304.172	2	1500	12

Appendix 2: Monthly real costs of wildlife law enforcement inputs

i. Serengeti National Park (SENAPA)

Year	Month	Salary of SPW (TZS)	Salary of PWI (TZS)	Salary of PWII (TZS)	Salary of SPR (TZS)	Salary of PRI (TZS)	Salary of PR II (TZS)	Salary of PR III (TZS)	Salary of PRIV (TZS)	Price of 1kg of meal (TZS)	Maintenance cost/vehicle (TZS)	Price of 1 litre of diesel (TZS)	Allowance for witness (TZS)	Allowance for prosecutor (TZS)
2010	January	1434173	1175370	890397.8	660125	527330	451830	403525	350579	1530.52	1019706	1650	60000	60000
	February	1417854	1161996	880266.1	652613.54	521329.6	446688.7	398933.4	346589.8	1513.104	742137.1	1684.61	59317.27	59317.27
	March	1404691	1151208	872093.9	646554.79	516489.7	442541.7	395229.7	343372.1	1499.057	983882	1619.999	58766.58	58766.58
	April	1396357	1144378	866919.9	642718.94	513425.5	439916.2	392884.9	341335	1490.164	618817.6	1686.331	58417.93	58417.93
	May	1401902	1148922	870362.4	645271.1	515464.2	441663.1	394445	342690.4	1496.081	524323.8	1768.295	58649.9	58649.9
	June	1404691	1151208	872093.9	646554.79	516489.7	442541.7	395229.7	343372.1	1499.057	839587.5	1758.1	58766.58	58766.58
	July	1409364	1155038	874995	648705.67	518207.9	444013.9	396544.5	344514.4	1504.044	342879.4	1751.174	58962.08	58962.08
	August	1403760	1150445	871515.9	646126.33	516147.4	442248.4	394967.8	343144.6	1498.064	1283018	1759.871	58727.63	58727.63
	September	1403760	1150445	871515.9	646126.33	516147.4	442248.4	394967.8	343144.6	1498.064	1226720	1822.514	58727.63	58727.63
	October	1404691	1151208	872093.9	646554.79	516489.7	442541.7	395229.7	343372.1	1499.057	818849.1	1774.751	58766.58	58766.58
	November	1400975	1148162	869786.7	644844.33	515123.3	441371	394184.1	342463.7	1495.091	512730.4	1826.713	58611.11	58611.11
	December	1379983	1130959	856754.1	635182.17	507404.8	434757.6	388277.8	337332.4	1472.689	780947.1	1839.755	57732.9	57732.9
2011	January	1348360	1105042	837121.3	620626.75	495777.5	424795	379380.3	329602.3	1438.942	459169.4	1837.083	56409.93	56409.93
	February	1318975	1080960	818877.7	607101.26	484972.9	415537.3	371112.3	322419.2	1407.583	199620.7	1847.63	55180.57	55180.57
	March	1300352	1065698	807315.9	598529.54	478125.5	409670.3	365872.6	317866.9	1387.709	361500.7	1889.545	54401.47	54401.47
	April	1286141	1054051	798492.7	591988.24	472900.1	405193	361874	314392.9	1372.543	531735	2027.624	53806.92	53806.92
	May	1276838	1046426	792717	587706.22	469479.5	402262.2	359256.4	312118.9	1362.615	303200.9	2089.523	53417.72	53417.72
	June	1266910	1038290	786553.6	583136.74	465829.2	399134.5	356463.2	309692.1	1352.02	1270189	1969.039	53002.39	53002.39
	July	1584339	1298438	1060972	1148415.3	917392.7	786045.8	702009.9	609900.1	1331.318	308770.3	1922.362	52190.81	52190.81
	August	1562258	1280341	1046185	1132409.6	904606.7	775090.5	692225.8	601399.7	1312.763	1015821	1831.24	51463.41	51463.41
	September	1525926	1250566	1021855	1106074.4	883569.4	757065.1	676127.5	587413.7	1282.234	538666.7	1824.677	50266.59	50266.59
	October	1513053	1240015	1013234	1096743.1	876115.2	750678.2	670423.4	582458	1271.416	555658.5	1860.787	49842.52	49842.52
	November	1492901	1223500	999739.7	1082136.1	864446.6	740680.3	661494.4	574700.5	1254.483	472710.6	1808.956	49178.69	49178.69
	December	1463660	1199536	980158.3	1060940.8	847515.1	726172.9	648538	563444.2	1229.91	611206.2	1847.455	48215.45	48215.45

SENAPA Cont...

Year	Month	Salary of SPW (TZS)	Salary of PWI (TZS)	Salary of PWII (TZS)	Salary of SPR (TZS)	Salary of PRI (TZS)	Salary of PR II (TZS)	Salary of PR III (TZS)	Salary of PRIV (TZS)	Price of 1kg of meal (TZS)	Maintenance cost/vehicle (TZS)	Price of 1 litre of diesel (TZS)	Allowance for witness (TZS)	Allowance for prosecutor (TZS)
2012	January	1430201	1172115	957751.7	1036687.5	828140.8	709572.5	633712.3	550563.7	1201.796	279509	1728.271	47113.24	47113.24
	February	1402611	1149503	939275.7	1016688.9	812165.2	695884.2	621487.4	539942.8	1178.612	227383.9	1694.161	46204.38	46204.38
	March	1388136	1137641	929582.5	1006196.7	803783.7	688702.7	615073.7	534370.7	1166.449	792650.2	1767.37	45727.55	45727.55
	April	1376770	1128325	921970.8	997957.65	797202.1	683063.4	610037.3	529995.1	1156.898	253175	1755.166	45353.12	45353.12
	May	1371855	1124298	918679.7	994395.33	794356.4	680625.1	607859.7	528103.2	1152.768	628469.2	1708.228	45191.23	45191.23
	June	1370457	1123152	917743.7	993382.2	793547	679931.6	607240.4	527565.1	1151.593	1565170	1734.328	45145.19	45145.19
	July	1369062	1122009	916809.6	992371.12	792739.3	679239.6	606622.3	527028.2	1150.421	173867.4	1702.496	45099.24	45099.24
	August	1359377	1114071	910323.8	985350.81	787131.3	674434.5	602330.9	523299.8	1142.283	714000	1716.574	44780.19	44780.19
	September	1344432	1101823	900315.3	974517.37	778477.2	667019.4	595708.6	517546.4	1129.724	226853.9	1746.418	44287.86	44287.86
	October	1340412	1098529	897623.8	971604.01	776149.9	665025.3	593927.7	515999.2	1126.347	338605.4	1599.899	44155.46	44155.46
	November	1344432	1101823	900315.3	974517.37	778477.2	667019.4	595708.6	517546.4	1129.724	109850.2	1614.292	44287.86	44287.86
	December	1305926	1070266	874529.5	946606.43	756181	647915.4	578647	502723.5	1097.368	139122	1577.379	43019.42	43019.42
	Mean	1394599	1142938	900470.6	829651.7	662753.6	567864.5	507154.3	440611.2	1327.292	604736.2	1778.962	52032.98	52032.98
	Min	1266910	1038290	786553.6	583136.74	465829.2	399134.5	356463.2	309692.1	1097.368	109850.2	1577.379	43019.42	43019.42
	Max	1584339	1298438	1060972	1148415.3	917392.7	786045.8	702009.9	609900.1	1530.52	1565170	2089.523	60000	60000

ii. Ikorongo/Grumeti Game reserves (IGGR)

Year	Month	Salary of GO (TZS)	Salary of GW (TZS)	Salary of WO (TZS)	Salary of PL (TZS)	Salary of APL (TZS)	Salary of GS (TZS)	Salary of OS (TZS)	Price of 1kg of meal (TZS)	Maintenance cost/ vehicle (TZS)	Fuel cost/litre (TZS)	Allowance to witness (TZS)
2010	January	602839	346917	5602106	467386	416615	318673	222151	1561.609	1 497 291	1 650	5 000
	February	595979.386	342969.4839	5627336.39	462067.7	411874.4	315046.9	219623.2	1543.839	519 651	1 685	4 943
	March	590446.421	339785.4171	5575093.21	457777.9	408050.6	312122	217584.2	1529.507	816 711	1 620	4 897
	April	586943.443	337769.5511	5542017.51	455062	405629.8	310270.3	216293.4	1520.432	825 883	1 686	4 868
	May	589274.125	339110.7935	5564024.2	456869	407240.5	311502.3	217152.2	1526.47	1 483 398	1 768	4 887
	June	590446.421	339785.4171	5575093.21	457777.9	408050.6	312122	217584.2	1529.507	1 147 022	1 758	4 897
	July	631443.542	360154.1171	5593639.76	459300.8	409408.1	313160.4	218308.1	1534.595	837 001	1 751	4 914
	August	628932.832	358722.0928	5571398.65	457474.6	407780.2	311915.2	217440	1528.493	523 138	1 760	4 894
	September	628932.832	358722.0928	5571398.65	457474.6	407780.2	311915.2	217440	1528.493	750 508	1 823	4 894
	October	629349.896	358959.9721	5575093.21	457777.9	408050.6	312122	217584.2	1529.507	760 171	1 775	4 897
	November	627684.949	358010.3426	5560344.29	456566.9	406971.1	311296.3	217008.6	1525.46	1 136 933	1 827	4 884
	December	618279.898	352646.0182	5477029.68	449725.8	400873.2	306631.9	213757	1502.603	1 417 028	1 840	4 811
2011	January	604111.803	344565.0146	5641574.02	463236.5	412916.9	315843.9	220179.2	1468.171	663 014	1 837	4 701
	February	590946.229	337055.8144	5518625.65	453141	403918.1	308960.6	215380.8	1436.174	29 206	1 848	4 598
	March	582602.605	332296.8926	5440707.66	446743.1	398215.2	304598.4	212339.8	1415.897	1 571 106	1 890	4 533
	April	576235.363	328665.2325	5381246.38	441860.6	393863.1	301269.4	210019.2	1400.423	1 229 383	2 028	4 484
	May	572067.295	326287.9072	5342322.35	438664.5	391014.2	299090.3	208500.1	1390.293	282 614	2 090	4 451
	June	567619.404	323750.9797	5300785.16	435253.9	387974	296764.8	206878.9	1379.483	34 754	1 969	4 417
	July	603191.839	340114.4788	5219618.84	428589.2	382033.3	292220.7	203711.2	1358.36	3 357 943	1 922	4 349
	August	594784.984	335374.2073	5146871.54	422615.8	376708.8	288147.9	200872	1339.429	644 114	1 831	4 289
	September	580952.775	327574.8071	5027176.85	412787.6	367948.1	281446.8	196200.6	1308.279	629 134	1 825	4 189
	October	576051.598	324811.2402	4984765.35	409305.1	364843.9	279072.4	194545.3	1297.242	1 691 449	1 861	4 154
	November	568379.435	320485.2303	4918375.57	403853.8	359984.7	275355.6	191954.3	1279.964	1 456 742	1 809	4 098
	December	557246.867	314208.0441	4822041.78	395943.7	352933.9	269962.3	188194.6	1254.894	1 222 303	1 847	4 018

IGGR conts...

Year	Month	Salary of GO (TZS)	Salary of GW (TZS)	Salary of WO (TZS)	Salary of PL (TZS)	Salary of APL (TZS)	Salary of GS (TZS)	Salary of OS (TZS)	Price of 1kg of meal (TZS)	Maintenance cost/ vehicle (TZS)	Fuel cost/litre (TZS)	Allowance to witness (TZS)
2012	January	544508.103	307025.1914	5029856.36	413007.2	368144.4	281596.6	196305.2	1226 207	2 055	1 728	3 926
	February	534004.036	301102.3905	4932825.77	405039.9	361042.6	276164.3	192518.2	1202.553	2 502 698	1 694	3 850
	March	528493.159	297995.0387	4881919.41	400859.9	357316.6	273314.4	190531.5	1190.142	1 760 892	1 767	3 811
	April	524165.682	295554.9565	4841944.64	397577.6	354390.8	271076.4	188971.3	1180.397	1 073 380	1 755	3 779
	May	522294.616	294499.9414	4824660.8	396158.4	353125.8	270108.7	188296.8	1176.184	1 598 752	1 708	3 766
	June	521762.477	294199.8905	4819745.2	395754.7	352766	269833.5	188104.9	1174.985	2 291 244	1 734	3 762
	July	568085.018	316468.8601	4814839.6	395351.9	352406.9	269558.9	187913.5	1173.789	968 850	1 702	3 758
	August	564066.225	314230.0707	4780778.08	392555.1	349913.9	267652	186584.1	1165.486	1 192 808	1 717	3 732
	September	557864.598	310775.2674	4728215.8	388239.2	346066.8	264709.3	184532.7	1152.672	587 304	1 746	3 691
	October	556196.841	309846.1933	4714080.63	387078.5	345032.2	263917.9	183981.1	1149.226	1 979 636	1 600	3 680
	November	557864.598	310775.2674	4728215.8	388239.2	346066.8	264709.3	184532.7	1152.672	0	1 614	3 691
	December	541886.922	301874.4223	4592796.03	377119.7	336155.2	257127.8	179247.6	1119.658	0	1 577	3 585
	Mean	578220.423	327863.601	5204404.56	427339.9	380919.6	291368.9	203117.3	1354.253	1069003	1778.962	4336.082
	Min	521762.477	294199.8905	4592796.03	377119.7	336155.2	257127.8	179247.6	1119.658	0	1577.379	3584.951
	Max	631443.542	360154.1171	5692106	467386	416615	318673	222151	1561.609	3357943	2089.523	5000

iii. Ikona Wildlife Management Area (IWMA)

Year	Month	Salary of GO (TZS)	Salary of GS (TZS)	Price of 1kg of meal (TZS)	Maintenance cost/vehicle (TZS)	Price of 1 litre of diesel (TZS)
2010	January	172115.7	108654.5	1099.428	0	1650
	February	170157.22	107418.2	1086.918	61788.82	1684.61
	March	168577.51	106420.9	1076.827	0	1619.999
	April	167577.38	105789.6	1070.439	92495.06	1686.331
	May	168242.81	106209.6	1074.689	2226741	1768.295
	June	168577.51	106420.9	1076.827	1943705	1758.1
	July	169138.32	106775	1080.409	5412227	1751.174
	August	168465.8	106350.4	1076.114	3601962	1759.871
	September	168465.8	106350.4	1076.114	675367.8	1822.514
	October	168577.51	106420.9	1076.827	2977507	1774.751
	November	168131.54	106139.4	1073.978	48842.59	1826.713
	December	165612.31	104549	1057.886	0	1839.755
	January	161817.25	102153.3	1033.644	0	1837.083
2011	February	158290.72	99927	1011.118	0	1847.63
	March	156055.8	98516.12	996.8418	65735.11	1889.545
	April	154350.27	97439.44	985.9474	538069.2	2027.624
	May	153233.81	96734.64	978.8157	982440.9	2089.523
	June	152042.4	95982.51	971.2053	12367.22	1969.039
	July	149714.31	94512.82	956.3341	86984.69	1922.362
	August	147627.7	93195.57	943.0054	0	1831.24
	September	144194.49	91028.23	921.075	128598.7	1824.677
	October	142978	90260.27	913.3044	4183366	1860.787
	November	141073.75	89058.14	901.1406	671698.9	1808.956
	December	138310.61	87313.8	883.4904	200897.7	1847.455
	January	135148.8	85317.79	863.2936	2230027	1728.271
2012	February	132541.65	83671.93	846.6399	985693.4	1694.161
	March	131173.84	82808.44	837.9026	70496.65	1767.37
	April	130099.74	82130.38	831.0416	243773	1755.166
	May	129635.34	81837.21	828.0751	1009798	1708.228
	June	129503.26	81753.83	827.2314	129040	1734.328
	July	129371.45	81670.62	826.3895	413409.7	1702.496
	August	128456.24	81092.86	820.5434	6530.445	1716.574
	September	127043.92	80201.28	811.5219	110719.6	1746.418
	October	126664.12	79961.52	809.0958	4021289	1599.899
	November	127043.92	80201.28	811.5219	52407.3	1614.292
	December	123405.29	77904.25	788.2793	549393.8	1577.379
	Mean	149261.56	94227	953.4421	937038.1	1778.962
	Min	123405.29	77904.25	788.2793	0	1577.379
	Max	172115.7	108654.5	1099.428	5412227	2089.523

Appendix 3: Component of the meal consumed in three DMUs

Component of meal consumed	DMU		
	SENAPA	IGGR	IWMA
	Weight (kg)/month	Weight (kg)/month	Weight (kg)/month
Sugar	166.0156	153	26.4
Cooking oil	99.60938	214.2	13.2
Potatoes	361.3281	183.6	-
Wheat flour	83.33984	153	-
Maize flour	172.3438	765	56.1
Rice	228.5156	673.2	56.1
Beans	111.6016	275.4	56.1
Groundnuts	140.625	-	-
Vegetable	609.375	61.2	3.3
Onion	78.125	61.2	5.61
Tomatoes	351.5625	91.8	5.61
Dagaa	78.125	-	56.1
Tea leaves	7.03125	3.06	1.32
Milk powder	13.67188	61.2	-
Salt	33.75	27.54	1.32
Milo	3.125	-	-
Blue band	31.83594	-	-
Fruits	375	306	-
Millet flour	46.875	-	-
Super gate	38.08594	-	-
Meat(beef and chicken)	-	612	13.2
Total	3029.94	3641.4	294.4
Meal(kg)/person/day	0.808	1.19	0.892

Appendix 4: Monthly efficiencies scores for three DMUs - CRS

Year	Month	Constant Return to Scale								
		SENAPA			IGGR			IWMA		
		TE	AE	CE	TE	AE	CE	TE	AE	CE
	January	0.56	0.863	0.483	0.278	0.817	0.227	0.091	0.949	0.086
	February	0.285	0.842	0.234	0.327	0.639	0.209	0.277	0.941	0.26
	March	0.248	0.835	0.207	0.258	0.818	0.211	0.182	0.949	0.172
	April	0.699	0.843	0.589	1	0.495	0.495	0.091	0.951	0.087
2010	May	1	0.847	0.847	0.279	0.824	0.23	0.545	0.934	0.509
	June	1	0.917	0.917	0.656	0.784	0.514	0.431	0.969	0.418
	July	1	1	1	1	1	1	0.667	1	0.667
	August	0.577	0.899	0.519	0.707	0.937	0.662	1	1	1
	September	1	1	1	1	1	1	0.172	0.969	0.167
	October	0.847	0.853	0.722	1	0.973	0.973	0.25	1	0.25
	November	1	0.805	0.805	1	0.869	0.869	0.086	0.97	0.083
	December	0.725	0.413	0.3	0.932	0.972	0.906	0.167	1	0.167
	January	0.699	0.721	0.504	0.979	0.846	0.828	0.182	0.952	0.173
	February	0.431	0.749	0.323	1	0.714	0.714	0.092	0.945	0.087
	March	1	0.841	0.841	0.593	0.88	0.522	0.091	0.952	0.087
	April	0.662	0.896	0.593	0.493	0.834	0.411	0.091	0.95	0.086
	May	0.543	0.918	0.498	1	0.822	0.822	0.273	0.945	0.258
	June	0.517	0.856	0.443	0.801	0.658	0.527	0.783	0.98	0.767
2011	July	0.895	0.844	0.755	0.999	0.797	0.796	0.696	0.977	0.68
	August	0.803	0.807	0.648	0.374	0.746	0.279	0.924	0.996	0.92
	September	0.55	0.837	0.46	0.577	0.872	0.503	0.603	0.97	0.584
	October	0.531	0.803	0.426	0.798	0.82	0.654	0.5	1	0.5
	November	0.513	0.784	0.402	0.442	0.74	0.327	0.258	0.969	0.25
	December	0.269	0.634	0.171	0.538	0.484	0.26	0.083	1	0.083
	January	0.749	0.57	0.427	0.709	0.421	0.298	0.273	0.935	0.255
	February	0.477	0.789	0.376	1	0.956	0.956	0.185	0.919	0.17
	March	0.649	0.673	0.437	0.702	0.554	0.389	0.083	1	0.083
	April	1	0.653	0.653	0.503	0.531	0.267	0.172	0.969	0.167
	May	1	0.51	0.51	1	0.486	0.486	0.167	0.987	0.165
2012	June	0.651	0.568	0.37	0.94	0.405	0.38	0.344	0.969	0.333
	July	0.585	0.523	0.306	0.574	0.616	0.354	0.5	1	0.5
	August	0.984	0.59	0.581	1	0.683	0.683	0.417	1	0.417
	September	0.57	0.602	0.343	1	0.842	0.842	0.689	0.969	0.668
	October	0.531	0.67	0.322	0.494	0.389	0.192	0.083	0.993	0.082
	November	0.723	0.602	0.435	0.858	0.523	0.449	0.172	0.869	0.149
	December	0.514	0.483	0.248	1	0.377	0.377	0.083	0.915	0.076
Mean		0.689	0.749	0.519	0.745	0.726	0.545	0.325	0.966	0.317
STD		0.229	0.152	0.223	0.261	0.190	0.263	0.261	0.030	0.259
Min		0.248	0.413	0.171	0.258	0.377	0.192	0.083	0.869	0.076
Max		1	1	1	1	1	1	1	1	

Monthly efficiency scores for three DMUs - VRS

Year	Month	Variable Return to Scale								
		SENAPA			IGGR			IWMA		
		TE	AE	CE	TE	AE	CE	TE	AE	CE
2010	January	1	1	1	1	0.808	0.808	1	0.993	0.993
	February	1	0.98	0.98	1	0.829	0.829	1	1	1
	March	1	0.965	0.965	1	0.896	0.896	1	0.993	0.993
	April	1	0.992	0.992	1	0.91	0.91	1	0.998	0.998
	May	1	1	1	1	0.985	0.985	1	1	1
	June	1	0.996	0.996	1	0.98	0.98	1	0.979	0.979
	July	1	1	1	1	1	1	1	0.988	0.988
	August	1	0.775	0.775	1	0.985	0.985	1	1	1
	September	1	1	1	1	1	1	1	0.968	0.968
	October	1	0.8	0.8	1	1	1	1	0.981	0.981
	November	1	0.865	0.865	1	1	1	1	0.96	0.96
	December	1	0.702	0.702	1	0.984	0.984	1	0.957	0.957
2011	January	1	0.772	0.772	1	0.829	0.829	1	0.994	0.994
	February	1	0.721	0.721	1	0.871	0.871	1	1	1
	March	1	0.865	0.865	1	0.814	0.814	1	1	1
	April	1	0.782	0.782	1	0.862	0.862	1	0.997	0.997
	May	1	0.738	0.738	1	1	1	1	0.996	0.996
	June	1	0.705	0.705	1	0.718	0.718	1	0.981	0.981
	July	1	0.805	0.805	1	0.874	0.874	1	0.979	0.979
	August	1	0.762	0.762	1	0.783	0.783	1	0.984	0.984
	September	1	0.728	0.728	1	0.787	0.787	1	0.962	0.962
	October	1	0.698	0.698	1	0.888	0.888	1	0.985	0.985
	November	1	0.697	0.697	1	0.8	0.8	1	0.966	0.966
	December	1	0.692	0.692	1	0.978	0.978	1	0.957	0.957
2012	January	1	0.724	0.724	1	0.81	0.81	1	0.997	0.997
	February	1	0.709	0.709	1	1	1	1	0.986	0.986
	March	1	0.717	0.717	1	0.835	0.835	1	0.955	0.955
	April	1	0.801	0.801	1	0.82	0.82	1	0.96	0.96
	May	1	0.724	0.724	1	0.879	0.879	1	0.956	0.956
	June	1	0.662	0.662	1	0.812	0.812	1	0.959	0.959
	July	1	0.639	0.639	1	0.798	0.798	1	0.964	0.964
	August	1	0.712	0.712	1	0.833	0.833	1	0.955	0.955
	September	1	0.627	0.627	1	0.842	0.842	1	0.961	0.961
	October	1	0.631	0.631	1	0.8	0.8	1	0.978	0.978
	November	1	0.659	0.659	1	0.814	0.814	1	0.858	0.858
	December	1	0.632	0.632	1	0.821	0.821	1	0.882	0.882
Mean		1	0.785	0.785	1	0.879	0.879	1	0.973	0.973
STD		0	0.126	0.126	0	0.084	0.084	0	0.030	0.030
Min		1	0.627	0.627	1	0.718	0.718	1	0.858	0.858
Max		1	1	1	1	1	1	1	1	1

Appendix 5: Potential improvement of inputs and outputs to efficient DMU

DMU	Input/ output	Mean input/ output	Mean Technical Efficiency		Mean slacks value		Target input/output		Potential improvement (%)	
			CCR	BCC	CCR	BCC	CCR	BCC	CCR	BCC
SENAPA	SPW	4	0.689	1.000	0	0	3	4	25	0
	PWI	4	0.689	1.000	0	0	3	4	25	0
	PWII	8	0.689	1.000	1	0	5	8	37.5	0
	SPR	5	0.689	1.000	1	0	2	5	60	0
	PRI	8	0.689	1.000	1	1	5	7	37.5	12.5
	PRII	34	0.689	1.000	8	4	15	30	55.9	11.8
	PRIII	12	0.689	1.000	2	1	6	11	50	8.3
	PRIV	216	0.689	1.000	11	14	138	202	36.1	6.5
	RTN	3029	0.689	1.000	212	0	1875	3029	38.1	0
	VH	34	0.689	1.000	5	5	18	29	47.1	14.7
	FUEL	14294	0.689	1.000	2186	2025	7663	12269	46.4	14.2
	FW	36	0.689	1.000	2	5	23	31	36.1	13.9
	FP	33	0.689	1.000	3	2	20	31	39.4	6.1
	PA	74	0.689	1.000	2	9	53	83	28.4	-12.2
	CC	17	0.689	1.000	0	1	12	18	29.4	-5.9
IGGR	GO	2	0.745	1.000	0	0	1	2	50	0
	GW	16	0.745	1.000	1	1	11	15	31.25	6.25
	WO	2	0.745	1.000	0	0	1	2	50	0
	PL	5	0.745	1.000	0	0	4	5	20	0
	APL	17	0.745	1.000	1	0	12	17	29.4	0
	GS	70	0.745	1.000	4	1	48	69	31.4	1.4
	OS	22	0.745	1.000	1	0	15	22	31.8	0
	RTN	3624	0.745	1.000	178	64	2522	3560	30.4	1.8
	VH	9	0.745	1.000	0	0	7	9	22.2	0
	FUEL	6869	0.745	1.000	979	559	4138	6310	39.8	8.1
	FW	10	0.745	1.000	1	2	6	8	40	20
	FP	11	0.745	1	1	0	7	11	34.59	0
	PA	24	0.745	1.000	0	1	18	25	25	-4.2
	CC	5	0.745	1.000	0	1	4	6	20	-20
IWMA	GO	1	0.348	1.000	0	0	0	1	100	0
	GS	22	0.348	1.000	0	0	8	22	63.7	0
	RTN	298	0.348	1.000	2	18	102	280	65.8	6.0
	VH	2	0.348	1.000	0	0	1	2	50	0
	FUEL	1184	0.348	1.000	6	72	406	1112	65.7	6.1
	PA	4	0.348	1.000	0	1	1	5	75	-25

Key; for input/output abbreviations see page 31, and 64

Appendix 6: Checklists to key informant - (heads of DMU)

Name of the key informant....................Title/position........................Name of the DMU...................................Date..

1. Does your DMU have wildlife restrictions which you enforce?

   Yes ☐ No ☐

2. If yes, which law do you use?

   ....

3. What are the conservation restrictions given by your DMU?

   i. ....

   ii. ....

   iii. ....

   iv. ....

4. How do you enforce the wildlife law?

   ....

   ....

   ....

   What inputs do you use for the Law enforcement?

   i. ....

   ii. ....

   iii. ....

5. How much input you have been used per month since January 2010 to December 2012? (fill the input data form)

6. What are the output of the law enforcement

   i..

   ii..

   iii..

7. How much output has been delivered per month since January 2010 to December 2012? (fill the output data form)
8. Do you pay your staff per-diem patrol allowance? Yes No
9. If yes for how many days per month..............................

Shadow pricing

10. What is the prices/cost of the unit input per month?

    i. Salaries for law enforcement staff

Designation (eg. Game warden, park ranger IV, etc)	Basic salary per Month (TZS)

    ii. Patrol allowance per day per person..

    iii. Maintenance costs for Patrol vehicles (fill the table below)

Year	Patrol vehicle maintenance costs (TZS)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010												
2011												
2012												

    i. Allowance for attending the court for witnessing/person/day (TZS)

    ....

    ii. Allowance for prosecutor/day (TZS) ....

Appendix 7: Checklists to the court magistrate

Name of the magistrate.....................court of.................. Date..........................

1. Does your court receive unlawful cases of conservation from SENAPA, IGGR or IWMA? a) Yes from all b) Not from all.............................. (Please specify).
2. What are the unlawful cases you have received from SENAPA, IGGR, and/or IWMA for the past 3 years? (Give the frequency in each year below)

Unlawful restrictions	2010			2011			2012		
	SE	IG	IK	SE	IG	IK	SE	IG	IK
Unlawful entering into the protected area (PA)									
Unlawful possession of weapon inside the PA									
Unlawful grazing livestock inside the PA									
Unlawful hunting									
Unlawful possession of Government trophy									
Unlawful vegetation destruction inside the PA									

Note; SE - Serengeti national park, IG – Ikorongo/Grumeti game reserves, IK – Ikona wildlife management area.

3. How many cases had been cleared for the past three years (fill the output table)
4. How many offenders were convicted for every month for the past three years? (fill the output table)
5. How many offenders were not convicted? (fill the output table) Why?

   ....

   ....

   a) What is the frequency of court attendance by the wildlife officer/scouts witness for every month for the past three years (fill the input table)

   b) How can you rank the attendance of witnesses for wildlife cases proceedings?

DMU	Very good	Good	Satisfactory	Poor	Very poor
SENAPA					
IGGR					
IWMA					

6. What is the frequency of prosecution for every month for the past three years (fill the input table)

a) Do you get any support in prosecution of wildlife cases from a) SENAPA b) IGGR c) IWMA? .... (If yes, mention from where)

b) If yes what kind of support do you get?

....

....

....

In what ways the support help you in prosecution of wildlife cases?

....

....

....

Appendix 8: Input – Output Data Form (To be filled by head of DMU)

Form number…………………Name of the DMU………………………Name of the key informant………………………….. Date……………**Year……..**

Input		Jan	Feb	March	April	May	June	July	August	Sept	Oct	Nov	Dec
Personnel	Rank levels												
Meal ration	Rice(kg)												
	Maize Flour (kg)												
	Beans (kg)												
	Meat (Kg)												
	Cooking oil(litre)												
	Tomato (kg)												
	Union (kg)												
	Sugar (kg)												
	Vegetable (kg)												
	Wheat flour(kg)												
	Salt (100g)												
Equipment	Vehicle (Number)												
	Fuel (litre)												
	Frequency of witness to court attendance												
	Frequency of wildlife cases prosecution												
	Patrol man-days												
Output	Number of Poachers arrested												

Note: for meal ration, give cost incurred per item per month if quantity purchased is not known.

Appendix 9: Output Data Form (To be filled from court magistrate's responses and supplemented with available records)

Output		Jan	Feb	Marc	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cases submitted to court	Serengeti												
	Bunda												
	Tarime												
	Bariadi												
	Magu												
	Shinyanga												
	Ngorongoro												
	Meatu												
Total cases submitted to court													
Cases cleared at court of	Serengeti												
	Bunda												
	Tarime												
	Bariadi												
	Magu												
	Shinyanga												
	Ngorongoro												
	Meatu												
Total number of cases cleared													
Convicted offenders at Court of	Serengeti												
	Bunda												
	Tarime												
	Bariadi												
	Magu												
	Shinyanga												
	Ngorongoro												
	Meatu												
Total convicted offenders													
Un- convicted offenders at	Serengeti												
	Bunda												
	Tarime												
	Bariadi												
	Magu												
	Shinyanga												
	Ngorongoro												
	Meatu												
Total Un- convicted offenders													

Appendix 10: Questionnaire to law enforcement staff

Name of the respondent..........Age.......... Name of the DMU................ Date.........

1. For how long have you work in this DMU.................(Years)
2. For how long have you work in a wildlife law enforcement field...............(Years)
3. What is the level of your education .... (Years of schooling)
4. a. How do you conduct your patrol activities
   a) By foot b) by vehicle c) both d) other.............(specify)
   b. What is the estimate time (hours) do you use in patrolling per day (you can give the range) ....
   c. Is there a change in patrol time (hours) for the past 12 months?
   Yes☐ No☐
   d. If yes fill the table bellow (the data can be supplemented by patrol man-days from official reports)

Months	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Hours/day												

   e. Explain your answer if respond to 3 (d)
   ....
   ....
   What challenges do you face in law enforcement?
   ....
   ....
5. a. do you offered time to rest (off-days) Yes ☐ No ☐
   b. If yes how many days you have been offered for the past 12 months years

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Off-days												

   b. Do you satisfy with the time you get?
   (i) Very satisfy (ii) Fairly satisfy (iii) Neutral (iv) less satisfy (v) Very less satisfy
   c. Explain your answer
   ....
   ....

d. If not (i) how much days could be enough for you to rest per month

....

5. a. Have you ever get any incentive/motivation for the past 12 months?

Yes ☐ No ☐

b. If yes fill the table below

Months	Frequency of given incentives	Type(s) of incentive(s)	Cost	Reason of given incentives
Jan- 2012				
Feb				
March				
April				
May				
June				
July				
August				
Sept				
October				
November				
December				

6. a. Do you think wildlife law enforcement is efficient

(i) Very efficient (ii) Fairly efficient (iii) Efficient (iv) Less efficient

(v) Very less efficient

b. Explain your answer, why?

....

....

c. For responses which is not (i) in your opinion what should be done to increase the efficiency of law enforcement?

....

....

....

7. (a) Which month(s) has many poachers................................

(b) On your opinion, what do you think could be the reasons?

....

....

8. (i) What do you prefer to do for the arrested poachers

(a) Send to the police/court (b) KDU – Bunda (c) compounding (d) village authority (d) other.........................specify

Explain your answer...

....

a. Is it possible to totally eliminate poaching?

(1) Very difficult (2) Fairly difficult (3) Neutral (4) Fairly Easy (5) Very easy

b. Explain your answer

....

....

....

Appendix 11: Checklists for Market survey

1. What is the price of the following items?

i. 1kg of maize flour.................................

ii. 1kg of rice..

Rice variety (eg. kitumbo, magugu, etc)					
Price of 1kg.					

iii. 1litre of cooking oil (take the prices of each cooking oil in the market)

Type of cooking oil (eg. sun flower, korie, etc)					
Price of 1 litre.					

iv. 1kg of tomato...

v. 1kg of onions...

vi. 1kg of meat (take the prices of each type of meat in the market butcher)

Type of meat (eg. mutton, beef, etc)					
Price of 1 kg.					

vii. 1kg of vegetables...

Type of vegetable (eg. mnafu, mchicha, etc..)					
Price of 1 kg.					

viii. 1kg of sugar...

ix. 1 kg of beans ....

Beans varieties (eg. Soya,)					
Price of 1 kg.					

x. 1kg of wheat flour...
xi. Salt (100g)..
xii. 1kg of Dagaa...
xiii. 1Kg of potatoes...
xiv. 100 gm of tea leaves..

2. What is the price of one litre of diesel (fill the table below)

Year	Diesel price (TZS)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010												
2011												
2012												