KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

THE TREND ANALYSIS OF TIMBER SPECIES HARVESTING IN FOREST RESERVES IN GHANA

KNUST

BY

GEORGE ROCKSON ODAME

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF MATHEMATICS IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE
MASTER OF SCIENCE (MSc) IN INDUSTRIAL MATHEMATICS

COLLEGE OF SCIENCES

INSTITUTE OF DISTANCE LEARNING (IDL)

AUGUST, 2013

DECLARATION

I hereby declare that this submission is my own work and that to the best of my knowledge, it contains no material previously published by another person or material which has been accepted to the award of any other degree of the University, except where the acknowledgement has been made in the text.

KNUST

Odame George Rockson / PG 4068910 ………………… …………….

(Candidate / Index No.) Signature Date

I declare that I have supervised the student in the undertaken of the thesis reported herein and confirm that the student has my permission to present it for assessment

Emmanuel Harris ………………… ……………

(Academic Supervisor) Signature Date

Prof. S. K. Amponsah .....……………… ……………..

(Head of Department) Signature Date

DEDICATION

This work is dedicate to the most high God who in his own diverse way has brought me this far and also to my wife Josephine Asare Ayeh Odame, children and all the entire family.

KNUST

ACKNOWDGEMENT

I wish to express my profound and sincere gratitude to my supervisor, for supervising my project from the beginning to the end and imparting knowledge to me.

My warmest gratitude also goes to:

Mr. Emmanuel Harris, lecturer, Department of Mathematics, for his useful guidance and constructive criticism, which enabled me, produce this thesis.

I will like to thank, Prof. S. K Amponsah and Dr. Okyere Asare Gabriel and the entire department of Mathematics staff, for their encouragement and advice. Also to the Resource Management Support Centre for offering me with the relevant data for my analysis.

I would also like to express my sincere appreciation to my family for their support during my period of study and all persons who in diverse ways have contributed to the success of this project.

KNUST

ABSTRACT

Ghana has established 266 forest reserves of which 216 fall within the High Forest Zone (HFZ) and covers an area of 1,634,100 Hectares. The sustainable production of timber to provide a perpetual flow of wood products to domestic and export markets and provide revenue for the resource owners is very important in forest management. The study identifies the trend on timber exploitation in Ghana's forest reserves, using data on timber exploited from Sefwi Wiawso Forest District. This study also develops method of interpreting the changing demand of timber in Ghana with time series for the period between 1998-2011, the methods employed monitor's trends on removal of timber. Autoregressive Integrated Moving Average (ARIMA) models were developed on data on volume of timber extracted. The model selected for volume and stems were ARIMA (2,1,0) and ARIMA (2,1,0) respectively, based on the diagnostics of the residuals of each model and Minimum Information Criteria. Forecasting with ARIMA(2,1,0) for volume and ARIMA(2,1,0) for stems model for the period January, 1998 to December, 2011 agree well with the observation data series collected over the period.

LIST OF ABBREVIATION

ACF	-	Autocorrelation Function
AIC	-	Akaike Information Criterion
AICc	-	Akaike Information Criterion corrected
AR	-	Autoregressive
ARIMA	–	Autoregressive Integrated Moving Average
ARMA	-	Autoregressive Moving Average
BIC	–	Bayesian Information Criterion
FC	-	Forestry Commission
ITTO	-	International Tropical Timber Organization
KPSS	–	Kwiatkowski – Philips-Schmidt-Shin
MSE	–	Mean Square Error
PACF	–	Partial Autocorrelation Function
MoP	-	Manual of Procedural
TUC	-	Timber Utilization Contract
RMSC	-	Resource Management Support Centre
MLFM	-	Ministry of Lands Forestry and Mine

KNUST

TABLE OF CONTENTS

KNUST

KNUST

KNUST

LIST OF TABLES

KNUST

LIST OF FIGURES

KNUST

KNUST

CHAPTER 1

INTRODUCTION

BACKGROUND

During the last decade, there was a growing concern that the nation's forests were increasingly under threat and that there was a need to utilize them more efficiently in order to promote economic and social conditions that were compatible with environmental quality. There was growing awareness that mistaken government policies, the use of forest resources for political patronage as well as illegal exploitation were playing a role in the degradation of the forest resource wealth of the country. The demand for timber from natural forest (on and off reserve) has adversely affected timber stock in the natural forest. Harvesting and supply of timber has provided a trend which call for study.

Hawphorne and Abujuan (1993), reveal that Ghana has established 266 forest reserves of which 216 falls within the High Forest Zone (HFZ) and covers an area of 1,634,100 ha. The inventories carried out during the period 1986-94 have provided basic information on the composition and state of the forest. Currently, some 762,000 Ha has been allocated for timber production after allowing for those areas excluded for permanent protection or for convalescence. Lands were reserved to meet national needs for timber and preservation of bio-diversity and water-catchments; and at the same time, ensuring that the wishes of the local communities are incorporated into management plans.

According to ITTO report (1992) sustainable forest management is the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment.

KNUST

The strategic planning undertaken for each reserve in turn provides the basic definition of the area into its respective management zones. Those areas requiring permanent protection either on the basis of condition (slope, swamps, etc.) Biological value or susceptibility to fire is excluded from the potential timber production areas along with those areas that are currently too under stocked with economic timber tree species to be considered for timber production. The general objective of management of the timber production areas is:

The sustainable production of timber to provide a perpetual flow of wood products to domestic and export markets and provide revenue for the resource owners; and to fund forest management whilst maintaining environmental quality and social responsibility.

There is a national management regime for timber production within the HFZ - namely the use of a polycyclic selection felling silvicultural system using a feeling cycle of 40 years. FC MoP (1995)

The Ministry of Lands and Forestry has embarked on a strategy through application of the Timber Rights Act to manage concessions both on and off reserve through a process of competitive tender and the issue of Timber Utilisation Contracts (TUCs). There is a Logging Manual in place to prescribe a code of practice for timber operations that all TUC holders are required to adhere to as part of the TUC agreement.

KNUST

1.1.1 ANNUAL ALLOWABLE CUT (CONTROLLING THE HARVESTING OF FOREST PRODUCTS)

The term "Annual Allowable Cut" - AAC is the maximum volume that can be felled each year without reducing the long-term sustainability of the forest resource; it is analogous to the taking of interest (growth) from a bank account without eating into the capital. A national annual allowable cut of 500,000 m^3 has been set for the forest reserves using the results of the inventories and applied to 64 economic species making use of a yield formula and the adoption of a rotation of 40 years. The 64 species have been grouped in accordance with their level of cut related to the total stocks, namely: **18** Scarlet Star species comprising the main traditional commercial timbers now under threat of economic extinction where the level of cut is greater than 200% of the sustainable level;**16** Red Star species significantly being over cut and will eventually become economically extinct, the level of cut being between 50-200% of the level considered to be sustainable; and finally, **30** Pink Star species, some of which are being exploited but not at a rate to cause concern, i.e. less than 50% of the sustainable cut.-(FC MOP C,1995).

The figure of 683,100 m^3 has been rounded down to 500,000 m^3 since many of the Pink Star species are currently regarded as unsalable. The Annual Allowable Cut (AAC) has presently also been set at 500,000 m^3 for off -reserves, to give a national figure for the total AAC of 1 million m^3.

At the level of a compartment, the allowable cut is calculated on the basis of a 100% survey of commercial timber species and the application of a yield formula on a species by species basis. Fine-grained protection rules define those areas that must be excluded from logging either on the basis on environmental concerns (excessive slopes, closeness to watercourses) or biological conservation (protection of Black Star species). On average, around 14% of the harvestable area of the compartment area is reduced by adherence to these rules.

1.1.2 DESIGNATION OF TIMBER PRODUCTION AREAS

The extent of the timber production areas is defined at the Strategic Planning Stage on a reserve by reserve basis, linked as appropriate to the Forest Management Units (FMUs).

Table 1.1: Forest management areas or zones

Area Category	Characteristics
PROTECTION	
Hill Sanctuaries	Healthy or regenerating forest. Slopes > = 30%, water sources, permanently inundated areas, or otherwise fragile soils to prevent erosion which in turn will compromise water quality.
Swamp Sanctuaries	Permanent wet areas
Provenance Protection Area	Area with high populations of key economic species.
Special Biological Protection Area	Areas of high plant GHI or presence of rare fauna species.
Fire Buffer Zones	Intact areas surrounding 'valuable' forest in fire prone areas.
Shelterbelts	Areas with a large boundary to area ratio which are therefore vulnerable.
Cultural sites	Culturally important areas identified during the settlement procedure or in special cases areas identified since and archaeological sites.
Research Area	Research Working Circles
PRODUCTION	
NTFP Production Areas	Areas identified by rights holders as important NTFP collecting grounds which do not fall into the protection designations.
Timber Production Areas	Healthy productive forest. >15m2/ha. basal area (characteristics need refining according to zone and soil type) which does not fall into protection, research or NTFP area designation.

Convalescence forest	'Regenerating forest' which is healthily regenerating forest but below the stocking limit or basal area in which logging should be allowed. The current basal area limit for this is between 5-15m^2/ha. This is only a guide, and needs to be linked to an assessment of the quality of the regeneration.
Conversion forest	'Conversion forest' which is heavily degraded forest which has no regeneration of indigenous tree species and may be available for afforestation. The current basal area limit for this is below 5m^2/ha.
Plantation area	Existing stands of artificially regenerated areas

The timber producing forest reserves have been zoned in accordance with the following needs:

- To meet national needs for timber
- Preservation of bio-diversity and water-catchment
- Ensuring that the wishes of the local communities are incorporated plans to the extent that good forest management practice allows.

Compartments form the basic planning unit on-reserve. All operations including logging should be recorded and monitored with respect to individual compartments. They will have already been demarcated -at least on paper - for most reserves. Where this is the case and there are records of operations carried out and the quantity of logs extracted, then the existing boundaries should be retained; it will cause major confusion if records refer to two sets of compartment numbers. Where, however, compartments are still to be identified then they should be laid out so that the area available for logging is around 100 -150 ha (more or less conforming to present practice, since the standard compartment was based on the imperial dimensions of 1 mile x 0.5 mile, or about 1,600 m by 800 m equivalent to 128 ha). However, in those areas subject to extreme changes in topography and vegetation cover and where timber production is not of importance then smaller compartments are likely to be more appropriate. As much as possible, the boundaries of compartments are linked to natural topographic features - steams, ridges or changes in slope, in order to aid field staff and the contractor with respect to establishing location in the forest. This needs to be based on the 1:50,000 scale Survey of Ghana maps (or a suitable enlargement), since the contours ensure a more logical fit. Where no such features are available then the former system of straight lines will have to be retained.

At this stage compartment demarcation will probably remain at the office level, but where there are concerns as to the suitability of areas, and then an early visit must be made to check on the status of the forest. It has been standard practice that the identification of compartments is not applied to large cohesive blocks within the protection zones - particularly the Hill Sanctuaries. However, where there are smaller protected areas within timber production areas, then it is less confusing if they are given a compartment number, though they continue to be excluded from consideration for timber. Many individual compartments will be composed of both large-grained protection areas as well as timber production areas. As long as the protection areas do not exceed 60% of the total area of the compartment, the compartment can still be considered as part of the TUC.

Following the fixing of compartments on the base map, it is necessary to identify a selection of the compartment corners or other key positions on the ground to ensure that future demarcation can be easily completed. Cutting of the compartments boundaries is not required at this time. The use of hand-held global positioning systems (GPS) will allow the team to quickly locate their position and allow the fixing of compartment markers relatively quickly without the need to resort to detailed trigonometric surveying. This work should be undertaken by the district survey teams. Guidance on the use of a GPS can be obtained from RMSC if required.

1.1.3 HARVESTING SCHEDULES

Harvesting schedules set the order in which compartments should be logged on the basis of their suitability or readiness for logging. This subject has been dealt with in detail in the MoP Section E covering the Preparation of Timber Harvesting Schedules for Forest Reserves which should be consulted in this context. In outline, the processes are as follows:- summarising the previous logging history for each compartment grouping compartments on the basis of similar treatment and hence likely to have a similar date of re-entry based on the 40 year logging cycle modification of groups taking into account practical problems of road construction and need to minimise extraction damage. field checking of those compartments known to be degraded through disturbance or site conditions. Those compartments classified as condition score 4 (mostly degraded) or worse should be excluded from the present cycle and put under the convalescence zone.

The main source of information on the state of the compartments with respect to previous logging history should be the Compartment Registers. In practice, many of these have not been well maintained. Where this is unfortunately the case, recourse has to be made to the felling registers, annual control reports, concessionaire files and monthly and quarterly reports. Resource Management Support Center (RMSC) maintain a logging register which is consulted where necessary.

The Harvesting Schedule MoP details the systematic summarising of the key information into three forms:-

Table 1.2: Compartment Information

Felling Series	Compt. No.	Size (ha)	District Assembly	Stool	Lease or TUC No.	Area Desig-nation	Remarks

Ideally no compartment is scheduled for re-entry following logging prior to the standard rotation of 40 years. The best compromise can be reached where possible and the additional factors that need to be taken into account to minimise the practical problems of logging for example, grouping compartments where possible in order to minimise road construction and extraction damage. Under no circumstances is re-entry allowed in less than 25 years - no matter how minimal previous logging had been, as this would extremely have adverse effect on regeneration.

1.2 STATEMENT OF PROBLEM

Tropical forests (TF) are among humanity's most important resources as they contain 50 percent of the world's biodiversity (SLW 1996). In addition, they regulate greenhouse gases and provide freshwater and timber and non-timber forest resources.

Some suggest that one way of controlling illegal logging would be the creation of a market tool such as certification of forest management practices.Sustainability of Ghana forest timber has been great concern globally.

Information about productivity or growth of valued species and their long-term yield is also scarce. In fact, databases (numerical, cartographic and bibliographic) that group together all available knowledge about climate, soil, topography, flora and fauna, are often lacking at the regional, local and national levels. Improving the flow and storage of management information is an economical and efficient way of continuously improving management and databases containing this information should be created and continuously updated using a permanent flow of field observations.

1.3 GENERAL OBJECTIVES

The specific objectives of this project are to:

1. To identify pattern of timber exploitation in Ghana forest reserves over the period of 1998- 2011
2. Develop a suitable time series forecasting model for the demand of timber in Ghana for the period of 1998-2011.

1.4 JUSTIFICATION OF WORK

This thesis is to provide some of the institutional measures and development instruments being taken in Ghana towards the feasibility of achieving sustainable management of the high forest for timber and other commodity products, as well as conserving other forest resources. This thesis, therefore, provides structures and regulatory system to ensure effective forest management and increase the productivity of the land and logging. The role of collaborative management approach of both natural reserved and unreserved high forests and to promote integrated farm forestry is explained. Effective management of the high forest resource demands close harmonizing of instruments and mechanisms, both internal and external to forestry, and which encourage stakeholders to participate actively in decision making that affects the resource quality and its production status.

1.5 SCOPE OF THE STUDY

The existence of High Forest Zone (HFZ) is important area that needs to be look at in this thesis. This is because of its environmental services which are all ways difficult to quantify. The research would take into account, timber demand, species of high demand in HFZ and its subsequent removal of the forest cover, more especially in Sefwi Wiawso Forest District.

There are 13 vegetation type in Ghana namely; DS, DSFZ, DSIZ , ME, ME/MS, MSNW, MSSE, SM,UE,WE,WE/ME. Every vegetation type comes with of tree species which are likely to be found or present. Formula for making prediction would be developed from existing data. Result that will be obtained from the Time Series would be represented graphically.

Validation of the analytical procedure would then be done.

1.7 LIMITATIONS

Technical and scientific issues. Good inventory data is a pre-requisite for any sustainable forest management project. However, more often than not, inventory data are unreliable.

Among the numerous mathematical models and computational tools, Time Series was used as the statistical tool for the data analysis.

The ARIMA module which was used for the data can predict for not more than one (1) years. Hence the module has to be revised after every six (6) or ten (10) months.

1.8 ORGANIZATION OF THE THESIS

Chapter 1 contains the background, problem statement, objectives and significance of the study. Chapter 2 deals with the review of relevant literature and the theory of time series analysis with special explanation on Box-Jenkins method.

Chapter 3 deals with modeling and data analysis: here we apply the Box-Jenkins method of modeling time series. Using the interrupted time series experiment the effectiveness of the control measure is tested.

Chapter 4 deals with the discussion of the results obtained from the Box-Jenkins approach and focuses on the analysis and modeling of the data

The final chapter will look at result, interpretation, conclusion and recommendation.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter reviews previous work on timber harvesting in forest reserves and many other related issues.

KNUST

2.1 RESERVATION OF FOREST LANDS TO MINIMISE FOREST DEGRADATION

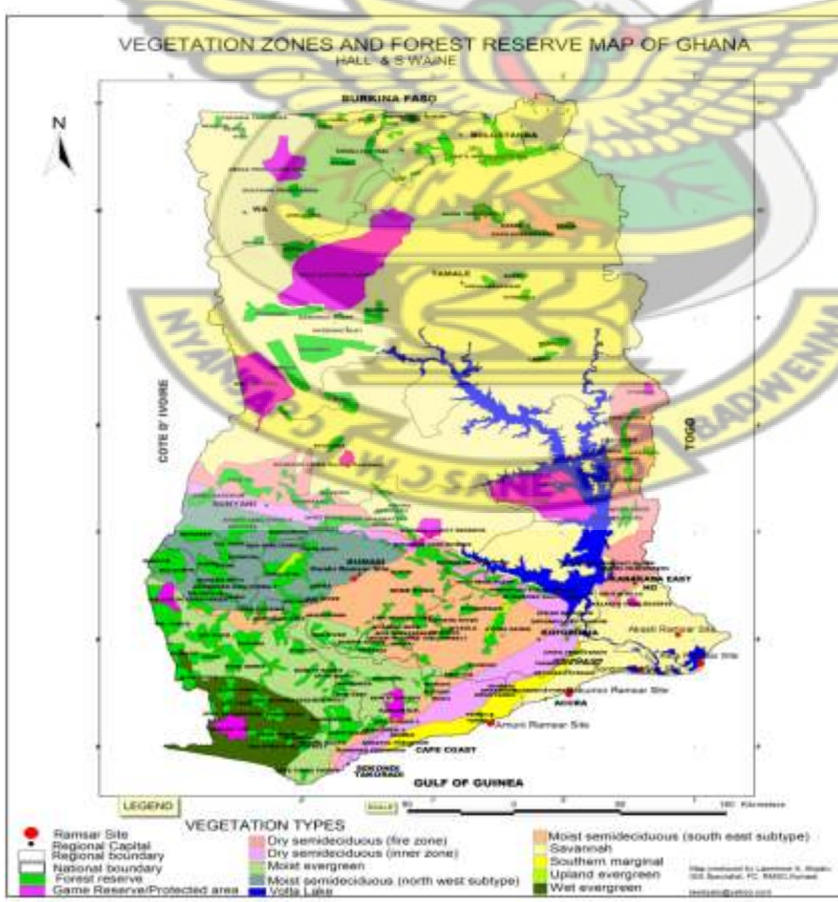
Ghana is richly endowed with renewable natural resources, which have played vital roles in its socio-economic development before and since independence in March 1957. In 1906, the colonial administration enacted legislation to control the felling of commercial tree species; in 1908, the Forestry Department was established; demarcation and reservation of the forest estate took place between 1928 and 1939; and the Forest Policy of 1948 was developed as a guiding instrument for the management of forests. The 1948 policy established 282 forest reserves and 15 wildlife protected areas, which occupied more than 38 000 sq km , or about 16 percent of the country's total land area. (FC Annual Report, 2009).

At the beginning of the twentieth century, the forest area of Ghana covered about 34 percent of the total land area. Forest reservation was started in 1927 by the colonial administration and ensured the reservation of 11 percent of the country's total land area. There was an additional 4 000 sq km of forest outside this gazeted area. The main aim of the reservation program was to ensure the protection of substantial areas of forest, but the process of forest land reservation ignored the traditional tenure system, which led to a negative attitude to reserves among the population, especially in forest fringe communities. This situation was aggravated by a failure to inform forest communities of their usufruct rights and by the focusing of forest management on forest protection by the central government. Boakye and Affum-Baffoe (2006).

All forest lands in Ghana are held in trust by the government, which manages them for the stool landowners. The Forest and Wildlife Policy of 1948 stipulated that the government manage forest resources single-handedly, without the collaboration of forest fringe communities, and did not yield many positive results. Passage of the current Forest and Wildlife Policy of 1994 led to some progress regarding stakeholder collaboration, but did not solve the ownership issue regarding trees outside forest reserves and on farmland; the lack of clear ownership status calls for a policy review. The policy of 1948 was driven by the need for commercial timber production, mainly for export. The 1994 policy, on the other hand, aims at the conservation and sustainable development of the nation's forest and wildlife resources for the maintenance of environmental quality and a steady flow of optimum benefits to all segments of society. The forest sector's potential to contribute to sustainable forest management (SFM) and poverty reduction for socio-economic development faces challenges related to forest ownership, resource tenure and the lack of effective participation from resource owners and local communities in forest management decision-making. This lack of participation is due to inadequate incentive structures to ensure. MLFM Publication (2011).

In Ghana, forest ownership is derived from the system of land inheritance. There are two forms of inheritance: the patrilineal system and the matrilineal system. As a result of the different historical settings of these two systems, they have different concepts of land, landacquisition and landownership. Under the patrilineal system, inheritance passes directly down the male line, while in the matrilineal system succession to property and land passes along the matrilineal line according to primogeniture in the following order: brothers, sisters' sons, sisters, and sisters' daughters. (Agyeman, 1991). The forestry sector impacts directly on the socio-economic development of Ghana and therefore wields the potential to accelerate to firm the nation's membership among the community of middle income countries. MLFM, Publication (2011.)

Figure 1: Map of Ghana Showing Forests Reserve



2.2 INVENTORY ON TIMBER STOCK.

Selective harvesting of compartments that make up the timber production area within a forest reserve is carried out in a sequence determined by the harvesting schedule. The schedule lists the compartments that can be considered for harvesting for each year of the period of the felling cycle. There is a Manual of Procedures for the Preparation of Harvesting Schedules for Forest Reserves which prescribes the steps to be followed in the design of the sequence of harvesting of Reserves prescribes the steps to be followed in the design of the sequence of harvesting of compartments to ensure a sustainable supply of timber over the period of the felling cycle.

The sequence of timber harvesting of compartments in a timber production area is planned by Forestry Department to ensure that a continuous and sustainable supply of timber is produced from TUC areas over the entire felling cycle. In order to achieve this, the number of compartments that constitute a timber production area is divided by forty to coincide with the forty year felling cycle. The sequence in which logging of compartments will be permitted is then determined and the year in which each compartment is to be logged is assigned. FC report, 2008.

Statistics have it that the forest cover of Ghana was about 8.2 million hectares by the turn of the 18th century but has reduced to about 1.2 million hectares. The rate of deforestation of about 65,000 hectares annually could eventually make Ghana a net importer of wood if we do not take urgent measures not only to arrest and reverse the situation but also to take steps to increase the national forest coverage and expanded National Forest Plantation Development Programme.

2.3 TIMBER EXPLOITATION

Large-scale timber exploitation has been controlled since colonial times through the allocation of cutting rights, where a legally defined area of forest is granted by the state to a private sector concessionaire for a given period of time. These cutting rights give the concessionaire the right to fell and market the timber obtained, under a regulatory regime that is set and overseen by the national forest authority. Since 1950, three different lengths of felling cycle have been applied to timber harvesting within the reserved forests. A felling cycle of 25 years was in operation throughout the 1960s. In 1972, a management system termed ‘salvage felling’ was introduced to remove so-called ‘over-mature’ trees (Adams, 2003).

Under this approach, all reserved forests with or without management plans were to be logged over a 15 year period. By the late 1970s, this system of timber exploitation was poorly controlled by an under-resourced Forestry Department. For the next twenty years, forest management controls and the monitoring of log movements were ineffective in preventing over-cutting. This now means there have been several generations of timber operators who have not had to work within the limitations imposed by ‘sustained yield’ forest management. Excess profits have become an expectation for those fortunate enough to acquire timber cutting rights. The introduction of a 40-year felling cycle in 1990, as forest management planning started to address the challenges facing sustained yield timber harvesting, therefore met with considerable opposition within the timber sector.

The timber industry has grown considerably in size, driven by two main factors: (i) a log export ban; and (ii) the under-pricing of timber. The log export ban was introduced for high value species in 1979 and extended to all species in 1994. Profit levels within the timber industry rose as a consequence of the ban, as log prices fell below comparable international log prices whilst exporters continued to sell their wood products at world prices (Birikorang et al., 2001). The second main driver of industrial expansion has been the under-pricing of timber by Government. Paramount has been the policy of administrative allocation of concessions and the application of unrevised stumpage charges. Companies benefited considerably from these policy measures, with an effective halving of forest taxation levels in the mid-1990s (World Bank, 2005).

Earnings from wood product exports increased steadily from $100 million in 1990 to $170 million in 1999. A drop in the average lumber price from $450 to $400 over the period was more than compensated by exchange rate adjustments. In terms of volume, the period also saw an increasing trend, with volumes growing from 220,000 m^3 to 430,000 m^3. In contrast, the non-revision of stumpage payments to reflect inflation caused an erosion in value to Government. The Ghana wood industry and log ban export study (Birikorang et al., 2001) points to a required 4.6 factor adjustment in stumpage between 1992 and 1997, which was not carried out, and an additional $6 million loss in real stumpage value between 2000 and 2001. Major reform did take place in 2003, with stumpage rates progressively adjusted back to their earlier real levels, although about one third of the stumpage value has been lost through illegal logging by the wood processing sector. In addition, about half of the actual stumpage claims have not been collected by the FC due to a combination of limited capacity and unwillingness to collect. Competitive bidding today remains the key instrument to address the issue of wrong timber pricing. But 40 per cent of productive forest lands are in the form of lease holdings with a further 50 per cent under salvage permits (Birikorang and Rhein, 2004). High profit making led to a systematic increase in installed capacity of the wood processing sector, from 2.5 million m^3 in 1990 to 5 million m3 by the end of 1999, with the increase largely associated with veneer and plymilling. This installed capacity is five times the annual allowable cut (AAC) of 1 million m^3 estimated in 19974. The MLF set an administrative cut limit of 2 million m3 in 2002, with the total increase in yield coming from off-reserves. This was supposed to be a transitional measure to accompany sector reforms. However, with the off-reserve inventory uncertain and a possible maximum forest reserve production area not exceeding 500,000 ha. (Davies, 2003), the AAC, based on the current market classification of commercial species, will be significantly below the 1997 1 million m^3 estimate. This means, first, that the industry is heading for a forced consolidation and second, that the future prospects of timber utilisation will be based on an appreciable increase in the use of lesser known species.

The Ghana wood industry and log ban export study (Birikorang et al, 2001) estimated that the forest industry directly employed 104,000 people in 1999. The distribution by product segment, indicated in Table 1, shows that over half were engaged in the tertiary sector, which largely comprised cottage industries and other informal establishments. This was at a time when that industry was already beginning a consolidation phase, with the tertiary sector shrinking by as much as half in 1999. Sawmilling, which accounted for 60 per cent of industry capacity, contributed only 15 per cent of direct employment. The areas of critical concern, therefore, will be logging which will be vulnerable to the enforcement of a limited, regulated harvest level, the tertiary sector and forest-related jobs which are rural-based.

Re-structuring of the timber industry will be problematic, as the loss of jobs in depressed rural areas is likely to bring a high social cost. Diversification of employment opportunities is a key policy area requiring Government consideration. Government faces two broad options in its attempts to manage the transition of the wood processing industry. A 'status quo' option, with continuing over-harvesting will eventually lead to high levels of unemployment and loss of livelihoods as timber supplies become exhausted. The implication of this option is that Government would have to resort to its budget to mitigate any adverse social impacts. The second option is to embark upon fiscal reforms that address timber pricing and industry inefficiency. Survivors in the industry will have long-term access to the resource, but they will pay for it, and thus create a financing opportunity for both investments in forest development as well as alternative job creation. Under this option the industry pays for the cost of its adjustment, not the Government. The employment and livelihoods issues need to be addressed by Government in a macroeconomic context that focuses on best job (and productivity) opportunities. These do not, necessarily, have to come from the forest sector.

The timber industry has not changed its ways despite warnings a decade ago about future resource scarcity, and has continued to depend on traditional high-value species and not to improve efficiency. It has also confirmed its annual resource consumption level of 2 million m^3, established in the Ghana Wood Industry Study in 2001. This partly influenced the Ministry's fixing of an administrative 2 million m^3 harvest level in 2002. Official records show that in 2003 and 2004 the industry consumed 1.2 million m3 and a little under 0.9 million m^3, respectively. Export records, on the other hand, indicate that timber consumption was 1.8 million m^3 and 1.2 million m^3 in those years. This 30 per cent difference has never been disclosed by industry. A question may be asked as to why the industry demands 2 million m^3 but reports consumption levels well below this figure. The difference in volume translates into a US$3 million loss in stumpage to the state in 2004. The industry presumably distributes such retained revenues informally among itself, FC staff and the financing of its patronage. Illegal logging in the formal sector undoubtedly existed before 2001, but was only objectively established by the Ghana Wood Industry Study.

2.4 CHAIN OF CUSTODY

The Ghanaian Government has procedures to monitor log movements through the use of a Log Measurement Conveyance Certificate (LMCC). This certificate is required to permit log haulage from forest to mill gate (ITTO, 2001). However, it is a paper-based manual system, which has made reconciliation between forest output and timber export very difficult to establish in practice. While the paper-based system, with its accompanying procedures, has increased transaction costs to industry, the FC has had major problems in monitoring and holding field staff to account. The volume of illegal logging in the formal sector and the loss of state revenue alluded to in preceding sections result directly from these weaknesses.

KNUST

2.5 VALIDATION OF LEGAL TIMBER

Government has recognised for some time that illegal logging is a major problem in Ghana's forests. It occurs during harvesting, transport and internal trade. Existing enforcement capacity is weak, leading to poor governance within the sector with a widespread disregard of forest rules and regulations. One of the main challenges to the introduction of reform is the presence of strong, long-standing alliances within the forest sector, involving producers, politicians and the forest authority who wish to maintain the status quo. Informal payments continue to define how business works. Illegal chainsaw milling in the informal sector is estimated to have distributed some US$4.5 million in 1999. Illegal felling by the formal sector in 2004 evaded US$7 million of tax, at an estimated average stumpage of US$9 per m^3 of roundwood. In a forest fiscal reform dialogue, in 2005, one large-scale integrated logger-processor indicated a cost of US$8 per m3 in informal social commitments, in order to retain traditional authority and other local support for harvest operations. This does not include the transaction costs of doing business with forest institutions and the established bureaucracy. It has been estimated that informal payments 'to get things done' amount to over US$ 1 million per year (Beeko, 2005).

A higher logging disturbance was recorded in Cameroun compared to Ghana even though less trees were removed because of the larger diameters of the felled trees. For example, most of the trees felled in Cameroun were greater than 100cm dbh whereas those felled in Ghana were above 70 cm dbh (Agyeman et al., 1995).

In Ghana the use of felling limits dates back to 1907, in the early days of timber exploitation in West Africa. There have been revisions of these felling limits in 1910, 1958, 1970 and recently in 1989 (Ghartey, 1992). Other countries in the West African sub-region, notably Liberia, Côte d'Ivoire and Cameroon, have similarly adopted felling limits as a control tool, with some variations in limits applied for similar species in the various countries. Generally, however, the minimum felling limits adopted in Ghana have been higher compared with those applied in these other countries. The basis for the felling limits applied in Ghana during the colonial era is not known, but according to Ghartey (1992), the limits prescribed in 1970 under the salvage felling regime were based on economic and physiological over maturity. The prescription of the 1989 felling limit has, however, been based on the relative abundance of a particular species and the degree to which it is threatened by extinction.

2.6 REGENERATION AFTER LOGGING

The natural regeneration of many species is gap size dependent (Schulze, 1960; Swaine and Whitmore, 1988). Even shade bearers regenerate more frequently in small gaps compared to the forest understorey (Swaine and Whitmore, 1988; Hawthorne, 1993). The sizes of gaps created determines the type of species which regenerate and the extent of natural regeneration. Medium sized openings resulting from felling gaps and skid trails favour the natural regeneration of most of the economic timber tree species, many of which are non-pioneer light demanders, compared to other gaps. Small (branch or small tree fall) and large (multiple tree fall, haulage roads and loading bays) results in reduced regeneration and a decline in the economic value of the tropical high forests of Ghana (Hawthorne, 1993; Swaine et al., 1998). This underscores the importance of gaps in regeneration (Hartshorn, 1978; Whitmore, 1990). Timber harvesting affects the forest micro-environment (Chazdon and Fetcher, 1984; Jans et al., 1993) and also stimulates the growth and regeneration of tree species.

A study by Swaine et al. (1998) which focused on damage immediately following timber exploitation show that disturbances due to logging markedly reduce the pre-existing tree seedlings in felling gaps and skid trails. However, enhanced regeneration was observed in small gaps and skid trails 3 years after timber harvesting in Bia-South Forest Reserve (Hawthorne, 1993) and 15 years after timber harvesting in wet and dry forests (Appiah et al., 1998). This is probably because, the stimulation of new seedling establishment significantly exceeds these losses due primarily to the local enhancement of light, the principal limiting factor for plants in forest.

The most abundant class (diameter size) of tree species following regeneration will be the one adapted for the predominant gap sizes (Denslow, 1984). More advanced regeneration was observed in the wetter forests compared to the drier ones for similar logging operations. This is probably because of the higher rainfall and greater density of seed trees following logging in the wetter forests (Swaine et al., 1998).

Reproduction, Dispersal and Recruitment Much of what needs to be known about forests, in a way which will facilitate understanding of empirical results on logging damage, is at the species by species (autecological) scale. The literature and inventory data on the autecology of Ghanaian trees is reviewed in Hawthorne (1995). Community-level regeneration studies will benefit from the resurrection of some silvicultural literature. Lowe (1984); Corbassion & Souvannavong, (1988).

Proximity of disturbed areas to remnant forest patches with 'seed trees' promotes more rapid recovery, particularly in species composition. Dispersal syndromes are potentially of great significance to logging prescriptions, especially concerning guidelines for retention of seed trees. When considering the distance that a tree can expect to project its offspring, it is profitable to group species into groups with similar dispersal syndromes (Alvarez Buylla & Martinez-Ramos, (1990); Appanah & Mohd.-Rasol, (1995).

Jesse and Yangdong (2005), Spatially patchy and temporally varied cycles of timber harvest across a landscape may have subtle effects on stream conditions that are difficult, but important, to assess. The objective of our study was to examine the relationship between benthic diatom composition and timber harvest in coastal Oregon watersheds. Physical habitat conditions, water chemistry, and periphyton composition were characterized for 46 sites from 2 sub basins with different timber harvest intensities (0.3 km2 /y vs 3 km2 /y, between 1972–1998). Landscape variables including geology, vegetative cover types, and harvest intensity, were quantified for the watershed upstream of each sample point. Nonmetric Multidimensional Scaling analysis of periphyton composition showed that the 1st axis was primarily driven by Achnanthidium minutissimum (r 5 20.91) Shannon diversity and species richness also were higher in the harvested group (p , 0.05). Our data suggest that diatom assemblages may be useful in assessing the long-term impact of timber harvest within coastal Oregon watersheds.

Yantai et al (2005), studied a method of fiting multiplicative seasonal ARIMA models to measured traffic traces. They also gave a general expression of the multiplicative ARIMA models with two periodicities and proposed a practical algorithm for building seasonal ARIMA models. They repeated the comparison with many prediction experiments on the GSM traces actually measured in the networking of /China Mobile of Tianjin and found that the relative error between our forecasting values and the actual values are all less than 0.02.This lends a strong support to our prediction method. Their experiments showed that the seasonal ARIMA model is a good traffic model capable of capturing the properties of real traffic.

Eyo et al (2002) monitored the microwave signal attenuation in Harmattan weather along Calabar-Akampkpo line-of-sight link in Nigeria. Line-of-sight (LOS) attenuation at 6.44GHz was measured at Calabar for ten month (Aug 93 – May 94) using the Nigerian Telecommunications radio signal. The measurement was made with the intent of highlighting microwave signal attenuation in Harmattan weather conditions. The results are presented in terms of mean signal level and fog attenuation, fade rate distribution, fade depth distribution and scintillation index. The observed attenuation values due to Harmattan (fog) and the calculated values using Altshuler's model are in fairly good agreement. Also, the statistics of fade distribution show fast fading of longer duration of the order of 15 to 38 fades per hour during this period (Harmattan). This shows that microwave LOS link in this region and regions with similar climatic characteristics are prone to signal degradation as well as fading in the Harmattan season.

Ho (2005) wrote that when radio wave signals pass through the Earth's environment, because the ionosphere and atmosphere are random media, the signals are affected by perturbations in the refractive index of the medium. This results in received signals with degraded amplitudes and phases. Complicated resultant phenomena include changes. As the signal frequency increases, the effects due to the troposphere become more significant. The degradation due to these propagation effects often cause unexpected communicative disruption. Thus, accurately simulating these effects becomes increasingly necessary, even though it is a difficult task sometimes.

Sundquist et al (2008) wrote on Success in Detecting a Range of Harvest Intensity using satellite imagery in New Hampshire Forests to track forest harvests over time, the results of the image analysis in identifying areas that are predominately cleared during timber harvests. However, the accuracy assessment showed less success in reliably picking out harvests of moderate and low intensity. The small patch cuts and some strip cuts fairly well, but selective removals just don't change the image spectrum enough to be well documented. Selective removals are invisible to detection. Classification show areas that are predominately cleared. The larger clear-cut operations are clearly evident. The smaller patch cuts of only a few acres each also appear in images. The issue has more to do with the resolution of the satellite imagery than the methodology; 30-meter pixels mean that openings created by harvest would need to be more than 100 feet across to be readily identified. Actually, the openings needs to be four or five grid cells across to be "seen" in the maximum likelihood analysis.

McDowell (2005), The purpose of this study was to compare the employment impact of Sealaska timber harvests with the impact of Tongass timber harvests. The primary difference between the two harvests, in terms of job creation, is that Sealaska harvests, in addition to logging jobs, create jobs in shiploading. Tongass harvests, because of the primary manufacturing requirement, create jobs in sawmills. This report examines these and other employment characteristics. Key findings of this study are summarized below: Sealaska harvested an average of 92 million board feet (mmbf) of timber from its lands in 2002 and 2003. During those same years the Tongass harvest averaged 42 mmbf. Sealaska and Tongass logging typically account for approximately 2.1 jobs per mmbf of timber harvested. This does not include stevedoring or sawmill jobs www.fs.fed.us/r10/TLMP/FEIS/FEIS_COV.PDF

Chapter 3 will cover sustainability, survey and measurement, theory of time series analysis.

KNUST

NYANSAPƆ WƆSANE NO BADWENMA

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

This chapter will look at the various methods that will be used in analyzing timber species harvesting in forest reserves. The process includes data identification, estimation, testing and forecasting.

KNUST

3.1 TIME SERIES

A time series is a set of numerical values of a particular variable listed in sequential order. Time-series analysis involves classifying and studying the pattern of movements of the values of the variables over regular intervals of time.

Time series is a time dependent sequence $Y_1, Y_2, \ldots Y_t$ or Y_t where $t \in N$ where 1,2,……..,n denote time steps.

3.2 OBJECTIVES OF TIME SERIES ANALYSIS

An observed time series can be assumed as the realization of a stochastic process. Once we understand how the process operates, we can develop a mathematical model to predict the future values of the time series. Thus, there are two main objectives of time series analysis:

1. To understand the underlying structure of the time series by breaking it down to it components,
2. To fit a mathematical model and then proceed to forecast the future. Basically, there are two approaches to time series analysis, which are associated with the

time domain (i.e. trend component) or the frequency domain (i.e. periodic component).The time domain approach represents time series as a function of time. Its main concern is to explore whether the time series has a trend (rising or declining) and if so, to fit a forecasting model. The frequency domain approach is based on the assumption that the most regular, and hence predictable, behavior of a time series is likely to be periodic. Thus, the main concern of this approach is to determine the periodic components embedded in the time series. The choice between the frequency domain and the time domain depends essentially upon the types of questions that are being asked in different fields of study. For example, economists have relatively greater interest in the time domain, whereas communication engineers have greater interest in the frequency domain. However, combining these two approaches would yield a better understanding of the data.

3.3 TIME SERIES METHOD

Two methods that can be used to do so are

1. Regression method
2. Box-Jenkins method

The regression method assumes that the characteristic of interest, referred to as the dependent variable, has some association with some independent variable. It attempts to capture this association and use it to forecast future values. Knowing the values of independent variables, the regression method can be used to predict the average value of the dependent variable.

3.4 ASSUMPTION OF THE REGRESSION METHOD

Two important assumptions, independence of residuals and constant variance of residuals are discussed next.

3.4.1 INDEPENDENCE OF THE RESIDUALS

The difference between an observed value of the dependent variable and its estimate using the Regression model is called a residual. Regression assumes that the residual are independent. This is, knowledge of one or more of the residual is assumed to provide no additional information to assess any other residual. If this assumption is not true then there is what is called autocorrelation among residuals. There should be no autocorrelation. The presence of autocorrelation can be tested using tests such as the Durbin Watson test. The second assumption is regarding the variance of the residual.

3.4.2 ASSUMPTION OF HOMOSCEDASTICITY

Residual are assumed to have a constant variance. For a given value of the independent variable price, there will be a distribution of residual, namely the difference between the observed and the estimated value of demand. This distribution will have a variance. What the constant variance assumption implies is that for all given values of price, the distribution will have the same variance. That is assumption of homoscedasticity. The heteroscedastic test can be used to check whether this assumption is valid. Violation of these two assumptions may make the regression estimates meaningless. If one is interested in the distribution of the forecasts and not just the average value, then more assumptions will have to be made.

3.5 MULTICOLLINEARITY

Detecting high multicollinearity. Multicollinearity is a matter of degree. There is no irrefutable test that it is or is not a problem. But, there are several warning signals: None of the t-ratios for the individual coefficients is statistically significant, yet the overall F statistic is. If there are several variables in the model, though, and not all are highly correlated with the other variables, this alone may not be enough. You could get a mix of significant and insignificant results, disguising the fact that some coefficients are insignificant because of multicollinearity. Check to see how stable coefficients are when different samples are used. For example, you might randomly divide your sample in two. If coefficients differ dramatically, multicollinearity may be a problem. Or, try a slightly different specification of a model using the same data. See if seemingly "innocuous" changes (adding a variable, dropping a variable, using a different operationalization of a variable) produce big shifts. In particular, as variables are added, look for changes in the signs of effects (e.g. switches from positive to negative) that seem theoretically questionable. Such changes may make sense if you believe suppressor effects are present, but otherwise they may indicate multicollinearity.

3.6 STATIONARITY AND NON-STATIONARITY

A key idea in time series is that of stationarity. Roughly speaking, a time series is stationary if its behaviour does not change over time. This means, for example, that the values always tend to vary about the same level and that their variability is constant over time. Their behaviour is well understood. This means that they play a fundamental role in the study of time series. Obviously, not all time series that we encounters are stationary. Indeed, nonstationary series tend to be the rule rather than the exception. However, many time series are related in simple ways to series which are stationary. Two important examples of this are: Trend models: The series we observe is the sum of a deterministic trend series and a stationary noise series. Shumway and Stoffer, (2000).

A simple example is the linear trend model:

$Y_t = \beta_0 + \beta_{1t} + \varepsilon_t$.

Another common trend model assumes that the series is the sum of a periodic "seasonal" effect and stationary noise. There are many other variations. Integrated models : The time series we observe satisfies

$Y_{t+1} - Y_t = \varepsilon_{t+1}$

where ε_t is a stationary series. A particularly important model of this kind is the random walk. In that case, the ε_t values are independent "shocks" which perturb the current state Y_t by an amount ε_{t+1} to produce a new state Y_{t+1}.

3.7 ARIMA Models

If $W_t = \nabla dY_t$ is an ARMA (p,q) series than Y_t is said to be an autoregressive intergrated moving average (p, d, q) series, denoted ARIMA(p,d,q). If we write

$\varphi(L) = 1 - \varphi 1L - \cdot \cdot \cdot - \varphi pL^p$

and

$\theta(L) = 1 + \theta 1L + \cdot \cdot \cdot + \theta qL^q$

then we can write down the operator formulation

$\varphi(L)\nabla^d Y_t = \theta(L)\varepsilon_t$.

Example 4.5.1 The IMA (1,1) Model This model is widely used in business and economics. It is defined by $Y_t = Y_{t-1} + \varepsilon_t + \theta\varepsilon_{t-1}$.

Y_t can be thought of as a random walk with correlated errors.

Notice that

$Y_t = Y_{t-1} + \varepsilon_t + \theta\varepsilon_{t-1}$

$= Y_{t-2} + \varepsilon_{t-1} + \theta\varepsilon_{t-2} + \varepsilon_t + \theta\varepsilon_{t-1}$

$= Y_{t-2} + \varepsilon t + (1 + \theta)\varepsilon_{t-1} + \theta\varepsilon_{t-2}$

.

.

.

$= Y-m + \varepsilon_t + (1 + \theta)\varepsilon_{t-1} + \cdot\cdot\cdot + (1 + \theta)\varepsilon-m + \theta\varepsilon-m-1$

If we assume that $Y-m = 0$ (i.e. observation started at time $-m$),

$Yt = \varepsilon_t + (1 + \theta)\varepsilon_{t-1} + \cdot\cdot\cdot + (1 + \theta)\varepsilon-m + \theta\varepsilon-m-1$

This representation can be used to derive the formulae

$\text{var}(Y_t) =1 + \theta^2 + (1 + \theta)^2(t + m)\sigma^2\varepsilon$

$\text{cor}(Y_k, Y_{t-k}) =(1 + \theta)^2 + (1 + \theta)^2(t + m - k) / \text{var}(Y_t)\text{var}(Y_{t-k})^{1/2}$

= square root of t + m – k / t=m

≈ 1

for m large and k moderate. (We are considering behaviour after “burn-in.”) This means that we can expect to see very slow decay in the autocorrelation function. The very slow decay of the acf function is characteristic of ARIMA series.

3.8 TIME SERIES COMPONENTS

The four components of time series are:

1. Secular trend
2. Seasonal variation
3. Cyclical variation
4. Irregular variation

KNUST

Secular trend: A time series data may show upward trend or downward trend for a period of years and this may be due to factors like increase in population, change in technological progress, large scale shift in consumers' demands, etc. For example, population increases over a period of time, price increases over a period of years, production of goods on the capital market of the country increases over a period of years. These are the examples of upward trend. The sales of a commodity may decrease over a period of time because of better products coming to the market. This is an example of declining trend or downward trend. The increase or decrease in the movements of a time series is called Secular trend. Brockwell and Davis (2002).

NYANSAPO W J SANE NO BADWENMA

3.8.1 Seasonal variation

Seasonal variation is short-term fluctuation in a time series which occur periodically in a year. This continues to repeat year after year. The major factors that are responsible for the repetitive pattern of seasonal variations are weather conditions and customs of people. More woollen clothes are sold in winter than in the season of summer. Regardless of the trend we can observe that in each year more ice creams are sold in summer and very little in Winter season. The sales in the departmental stores are more during festive seasons that in the normal days.

3.8.2 Cyclical variations

Cyclical variations are recurrent upward or downward movements in a time series but the period of cycle is greater than a year. Also these variations are not regular as seasonal variation. There are different types of cycles of varying in length and size. The ups and downs in business activities are the effects of cyclical variation. A business cycle showing these oscillatory movements has to pass through four phases-prosperity, recession, depression and recovery. In a business, these four phases are completed by passing one to another in this order.

3.8.3 Irregular variation

Irregular variations are fluctuations in time series that are short in duration, erratic in nature and follow no regularity in the occurrence pattern. These variations are also referred to as residual variations since by definition they represent what is left out in a time series after trend, cyclical and seasonal variations. Irregular fluctuations results due to the occurrence of unforeseen events like floods, earthquakes, wars, famines, etc.

3.9 TIME SERIES MODELS

Time series analysis provides tools for selecting a model that can be used to forecast future events. Modeling the time series is a statistical problem. Forecasts are used in computational procedures to estimate the parameters of a model being used to allocate limited resources or to describe random processes such as those mentioned above. Time series models assume that observations vary according to some probability distribution about an underlying function of time

$$X\ t = b_0 + b_{1t} + \varepsilon_t$$

Of course, Eqs. (1) and (2) are special cases of a polynomial model.

$$X_t = b_0 + b_1 t + b_2 t_2 + \ldots + b_n t^n + \varepsilon_t.$$

Modelling: to develop a simple mathematical model which explains the observed pattern of $Y_1, Y_2, \ldots, Y_T$. This model may depend on unknown parameters and these will need to be estimated.

Forecasting: On the basis of observations $Y_1, Y_2, \ldots, Y_T$, we may wish to predict what the value of Y_{T+L} will be ($L \geq 1$), and possibly to give an indication of what the uncetainty is in the prediction.

Control: We may wish to intervene with the process which is producing the Yt values in such a way that the future values are altered to produce a favorable outcome.

3.10 INTRODUCTION TO AUTOREGRESSIVE MODELS

Autoregressive models are based on the idea that the current value of the series Y_t, can be explained as a function of p past values, $Y_{t-1}, Y_{t-2}, \ldots, Y_{t-p}$, where p determines the number of steps into the past needed to forecast the current value.

3.10.1 AN AUTOREGRESSIVE MODEL OF ORDER P $[AR(P)]$

An autoregressive model of order p, abbreviated $AR(p)$, is of the form

$$Y_t = \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \cdots + \emptyset_p Y_{t-p} + w_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .(2)$$

Where Y_t is stationary, $\emptyset_1, \emptyset_2, \cdots, \emptyset_p$ are constants $(\emptyset_p \neq 0)$ and $w_t \sim WN(0, \sigma_w^2)$. The mean of Y_t in (2) is zero. If the mean, μ_t of Y_t is not zero, replace Y_t by $Y_t - \mu$. i.e

$$Y_t = \alpha + \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + \cdots + \emptyset_p Y_{t-p} + w_t$$

$$where\ \ \alpha = (1 - \emptyset_1 - \cdots - \emptyset_p).$$

The $AR(p)$ model in terms of the backshift operator is defined as;

$$\emptyset(B)Y_t = w_t \ \ where \ \ \emptyset(B) = 1 - \emptyset_1 B - \emptyset_2 B^2 - \cdots - \emptyset_p B^p$$

$$and \ \ B^k Y_t = Y_{t-k} \ \ is\ called\ the\ backshift\ operator$$

3.10.2 THE FIRST ORDER AUTOREGRESSIVE PROCESS $AR\ (1)$

$$Y_t = \alpha + \emptyset_1 Y_{t-1} + w_t$$

$$putting\ \alpha = 0\ we\ have\ \ Y_t = \emptyset_1 Y_{t-1} + w_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots .(3)$$

Dropping the subscript 1 from the coefficient of equation (3) and taking variance of both sides we obtain;

$$\gamma_0 = \emptyset\gamma_0 + \sigma_w^2 \qquad ; \gamma_0 = \frac{\sigma_w^2}{1 - \emptyset^2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

It implies that $\emptyset^2 < 1\ or\ |\emptyset| < 1$.

Multiply both sides of equation (3) by Y_{t-k} $(K = 1, 2, \cdots)$, and take the expected values

$E(Y_{t-k}Y_t) = \emptyset E(Y_{t-k}Y_{t-1}) + E(w_t Y_{t-k})$

$or\ \gamma_k = \emptyset\gamma_{k-1} + E(w_t Y_{t-k})$

Since the series is assumed to be stationary with zero mean, and since w_t is independent of Y_{t-k}, we obtain;

$E(w_t Y_{t-k}) = E(w_t)E(Y_{t-k}) = 0$

$\gamma_k = \emptyset\gamma_{k-1} \quad for\ k = 1,2,3,\cdots$

KNUST

Setting k=1, we get

$$\gamma_1 = \emptyset\gamma_0 = \frac{\emptyset\sigma_w^2}{1-\emptyset^2}$$

Setting k= 2, we get

$$\gamma_2 = \frac{\emptyset^2\ \sigma_w^2}{1-\emptyset^2}$$

In general

$$\gamma_k = \emptyset^k \frac{\sigma_w^2}{1-\emptyset^2}$$

And thus $\rho_k = \frac{\gamma_k}{\gamma_0} = \emptyset^k$ for k= 1, 2, 3,....

Autocorrelation function for several $AR(1)$ models

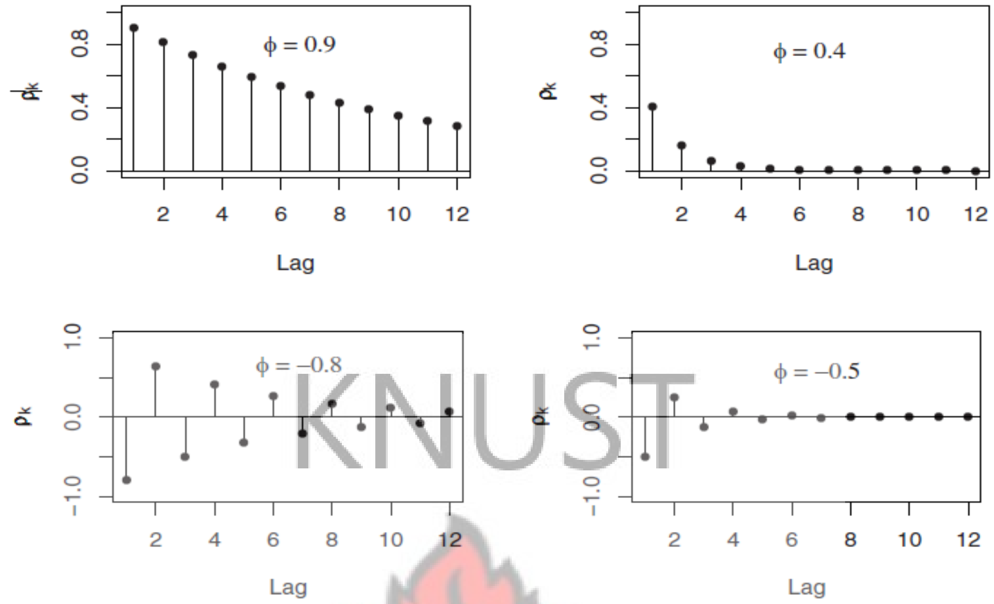


Figure 2: **AUTOCORRELATION FUNCTION FOR SEVERAL $AR(1)$ MODELS**

The requirement $|\emptyset| < 1$ is usually called the stationary condition for $AR(1)$ process. Since $|\emptyset| < 1$, the magnitude of the autocorrelation function decreases exponentially as the number of lags k, increases. If $0 < \emptyset < 1$, all correlations are positive; if $-1 < \emptyset < 0$, the lag 1 autocorrelation is negative($\rho_1 = \emptyset$) and the signs of successive autocorrelation alternate from positive to negative, with their magnitudes decreasing exponentially.

3.10.3 THE SECOND ORDER AUTOREGRESSIVE PROCESS $AR(2)$

Consider the series satisfying

$Y_t = \emptyset_1 Y_{t-1} + \emptyset_2 Y_{t-2} + w_t \dots \dots \dots (5)$

$where\ w_t\ is\ independent\ of\ Y_{t-1}, Y_{t-2}, Y_{t-3}, \dots$. Let $\emptyset(x) = 1 - \emptyset_1 x - \emptyset_2 x^2 - \dots - \emptyset_p x^p$ be the AR characteristics polynomial and the corresponding AR characteristics equation is $1 - \emptyset_1 x - \emptyset_2 x^2 - \ldots - \emptyset_p x^p = 0$. A stationary solution to equation (5) exists if and only if the roots of the AR characteristic equation exceed 1 in absolute value. In the second order case, the roots of the quadratic characteristics equation are;

$$\frac{\emptyset_1 \pm \sqrt{\emptyset_1^2 + 4\emptyset_2}}{-2\emptyset_2}$$

Thus the stationary conditions for $AR(2)$ model are

$$\emptyset_1 + \emptyset_2 < 1\,,\ \emptyset_2 - \emptyset_1\,,\ and\ |\emptyset_2| < 1$$

3.11 THE AUTOCORRELATION FUNCTION FOR THE $AR(2)$ PROCESS

To derive the autocorrelation function for the $AR(2)$ case, we take the defining recursive relationship of equation (5), multiply both sides by Y_{t-k}, and take expectations. Assuming stationarity, zero mean and that w_t is independent of Y_{t-k}, we get

$$\gamma_k = \emptyset_1 \gamma_{k-1} + \emptyset_2 \gamma_{k-2}\ \ for\ k = 1, 2, 3, \ldots \ldots\ldots\ \ldots\ldots\ldots \quad (6)$$

Dividing through by γ_0,

$$\rho_k = \emptyset_1 \rho_{k-1} + \emptyset_2 \gamma_{k-2}\ \ for\ k = 1, 2, 3, \ldots \quad \ldots\ldots\ldots\ldots (7)$$

Setting k =1 and using $\rho_0 = 1\ and\ \rho_{-1} = \rho_1\,, we\ get\ \ \rho_1 = \emptyset_1 + \emptyset_2\rho_1$

Thus $$\rho_1 = \frac{\emptyset_1}{1-\emptyset_2}$$

For k =2

$$\rho_2 = \frac{\emptyset_2(1 - \emptyset_2) + \emptyset_1^2}{1 - \emptyset_2}$$

KNUST

Successive values of ρ_k may be easily calculated numerically from the recursive relationship of equation (7).

3.12 THE PARTIAL AUTOCORRELATION FUNCTION

Since for $MA(q)$ models the autocorrelation function is zero for lags beyond q, the sample autocorrelation is a good indicator of the order of the process. However, the autocorrelations of an $AR(p)$ model do not become zero after a certain number of lags , they die off rather than cut off. So a different function is needed to help determine the order of autoregressive models. Such a function may be defined as the correlation between Y_t and Y_{t-k} after removing the effect of the intervening variables$Y_{t-1}, Y_{t-2}, Y_{t-3}, \dots, Y_{t-k+1}$. This coefficient is called the partial autocorrelation at lag *k* and will be denoted by $\emptyset_{kk}$.

3.13 SAMPLE DISTRIBUTION OF THE PARTIAL AUTOCORRELATION COEFFICIENTS

The partial autocorrelation coefficients of random data are approximately normal with mean $\mu_{\emptyset_{kk}} = 0$ and standard deviation $\sigma_{\emptyset_{kk}} = \frac{1}{\sqrt{n}}$ and n is the size of the sample. Thus for a random sample of size 40 we expect $-2\sigma\emptyset_{kk} \le \emptyset_{kk} \le 2\sigma_{\emptyset_{kk}}$ for the significant limits of two standard errors which is$\frac{-2}{\sqrt{40}} \le \emptyset_{kk} \le \frac{2}{\sqrt{40}}$. Hence any value of $\emptyset_{kk}$ lying outside this interval is said to be significantly from zero.

The table below shows the behaviour of the partial autocorrelation functions that is useful in specifying models;

Table 3.1 Shows the general behaviour of the ACF and PACF for ARMA models

General Behaviour of the ACF and PACF for ARMA models			
	$AR(p)$	$MA(q)$	$ARMA(p,q), p > 0, and\ q >$
ACF	Tails off	Cuts off after lag q	Tails off
$PACF$	Cuts off after lag p	Tails off	Tails off

3.14 THE BOX-JENKINS METHOD OF MODELLING TIME SERIES

The Box-Jenkins methodology is a statistical sophisticated way of analyzing and building a forecasting model which best represents a time series. The first stage is the identification of the appropriate $ARIMA$ models through the study of the autocorrelation and partial autocorrelation functions. For example if the partial autocorrelation cuts off after lag one and the autocorrelation function decays then $ARIMA\ (1,0,0)$ is identified. The next stage is to estimate the parameters of the $ARIMA$ model chosen.

The third stage is the diagnostic checking of the model. The Q-statistic is used for the model adequacy check. If the model is not adequate then the forecaster goes to stage one to identify an alternative model and it is tested for adequacy and if adequacy then the forecaster goes to the final stage of the process. The fourth stage is where the analyst uses the model chosen to forecast and the process end.

Below is a schematic representation of the box-Jenkins process, Makridakis et al., (1983).

The Box-Jenkins Process

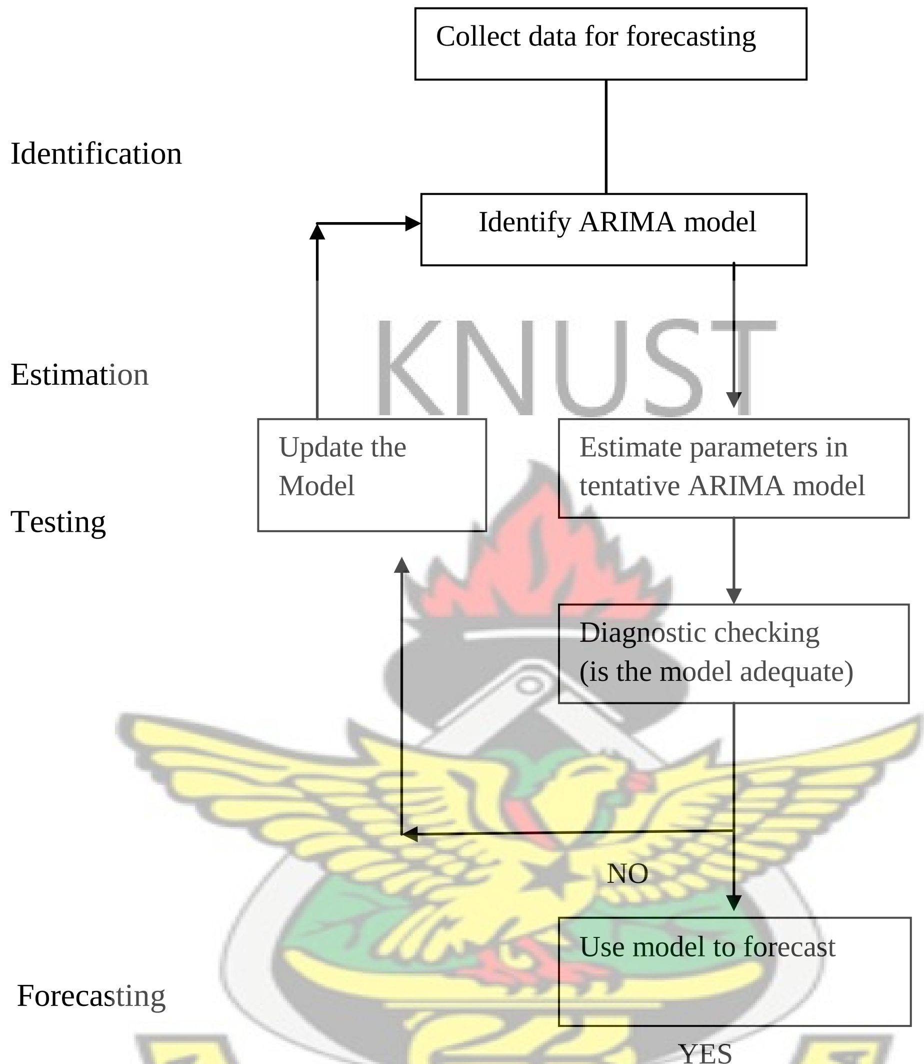


FIGURE 3: ABOVE IS SCHEMATIC REPRESENTATION OF THE BOX-JENKINS PROCESS

3.15 MAXIMUM LIKELIHOOD ESTIMATION

For any set of observations, $Y_1, Y_2, \dots, Y_n$ time series or not, the likelihood function L is defined to be the joint probability density of obtaining the data actually observed. However, it is considered as a function of the unknown parameters in the model with the observed data held fixed. For ARIMA models, L will be a function of the $\emptyset's, \theta, s$, μ, and σ_ε given the observations $, Y_1, Y_2, \ldots, Y_n$.The maximum likelihood estimators are then defined as those values of the parameters for which the data actually observed are most likely, that is, the values that maximize the likelihood function. The advantage of the method of maximum likelihood is that all of the information in the data is used rather than just the first and second moments, as is the case with least squares. Another advantage is that many large-sample results are known under very general conditions. One disadvantage is that we must for the first time work specifically with the joint probability density function of the process.

KNUST

3.16 OTHER SPECIFICATION METHODS

The Akaike's Information Criterion (AIC) which was proposed by Akaike uses the maximum likelihood method. In the implementation of the approach, a range of potential ARMA models are estimated by maximum likelihood method, and for each the AIC is calculated, given by

$$AIC(p,q) = -2\log(maximum\ likelihood) + 2k \quad ;where\ k = p + q + 1$$

Another approach to determining the $ARMA$ orders is to select a model that minimizes the Schwartz Bayesian Information Criterion (BIC) defined as

$$BIC = -2\log(maximum\ likelihood) + K\log(n)$$

3.17 ESTIMATION OF THE PARAMETERS OF THE MODEL IDENTIFIED

Once a model is identified the next stage of the Box-Jenkins approach is to estimate the parameters by either using the maximum likelihood estimation, the least square estimation or the Yule-walker estimation. In this study the estimation of the parameters was done using a statistical package called the R-software.

3.18 TEST THE MODEL FOR ADEQUACY

After identification of an appropriate model for a time series data, it is very important to check that the model is adequate. The error terms w_t are examined and for the model to be adequate the errors should be random. If the error terms are statistically different from zero, the model is not adequate.

The test statistic is the Q –statistic.

$$Q = n(n+2)\sum_{i=1}^{k}\frac{r_i^2}{n-1}$$

Which is approximately distributed as a χ^2 with $k-p-q$ degrees of freedom, where n is the length of the times series, k is the first k autocorrelations being checked ,p is the order of the AR process and q is the order of the MA process, and r is the estimated autocorrelation coefficient of the i^{th} residual term.

If the calculated value of Q is greater than χ^2 for $k-p-q$ degrees of freedom, then the model is considered inadequate and adequate if Q is less than χ^2 for $k-p-q$ degrees of freedom. If the model is tested inadequate then the forecaster should select an alternative model and test for the adequacy of the model.

KNUST

3.19 FORECASTING

The fourth stage of the Box-Jenkins approach is to forecast with model selected. Suppose the model chosen to fit a hypothetical data is

$$Y_t \; = \; = \; Y_{t-1} + \emptyset_1 \; (Y_{t-1} - \; Y_{t-2}) + w_t$$

And suppose further that the data is of length 60, $\emptyset_1$ = 0.2178

$$Y_{60} \; = \; 131.2, \qquad Y_{59} \; = \; 134.8$$

Then $Y_{61} \; = \; Y_{60} \; + 0.2178(Y_{60} - Y_{59})$

$$Y_{61} \; = \; 131.2 + \; 02178(131.2 - 134.8)$$

$$Y_{61} \; = \; 130.097$$

Hence, a forecast value for period 61 is 130.097

3.20 METHODOLOGY

The study "The trend of analysis of timber species harvesting in forest reserves in Ghana" was conducted using data available at the Resource Management Support Centre (RMSC). The data on monthly basis provides detail measurement of trees for volume and stem numbers from both Off Reserve and On Reserve from Sefwi Wiawso Forest District. The data for the study captures exploitation from January, 1998 to December, 2011. Box-Jenkins ARIMA time series modeling procedure was used for modeling the data. The method will be used to analyzing and forecasting in the future. Since ARIMA is going to be used, three models will be deployed. Step one will identify the appropriate ARIMA model. Step two estimate the parameters of the ARIMA model chosen, step three diagnostic checking of the model and finally the

KNUST

analysis uses the model chosen to forecast and the process ends. R-software was used in the data analysis.

KNUST

CHAPTER 4

DATA ANALYSIS AND RESULTS

4.0 INTRODUCTION

In this chapter, data will be analyzed using time series analysis described in Chapter 2 to find out whether the intervention has been effective or not effective on tree stems and volume extraction from the nation forest.

KNUST

4.1 ANALYSIS

4.1.1 DATA PROCESSING

The data obtained included the year, compartment or area, species, and volume harvested over a period of thirteen (14) years from 1998-2011. However, estimate on official trees felled during the period is available but Unofficial volume of tree felled could always be obtained by seeking expert opinion.

In general, there has been a down trend in the rates of extraction over the period under consideration.

4.1.2 PRELIMINARY ANALYSIS OF DATA

The figure below shows the trajectory of monthly volume of timber captured in at Sefwi Wiawso Forest District. From the figure, the change in volume saw a increase of 14,239.74m^3 in 1999 and a drop between 2000 and 2002 and then gradually to its minimum of 16107.07m^3 in 2003. From 2003, volume cut has gradually decreased to 1338.87m^3 in December, 2011.

4.1.3 DESCRIPTIVE ANALYSIS OF VOLUME CAPTURED IN GHANA AT SEFWI WIAWSO FOREST DISTRICT (M3)

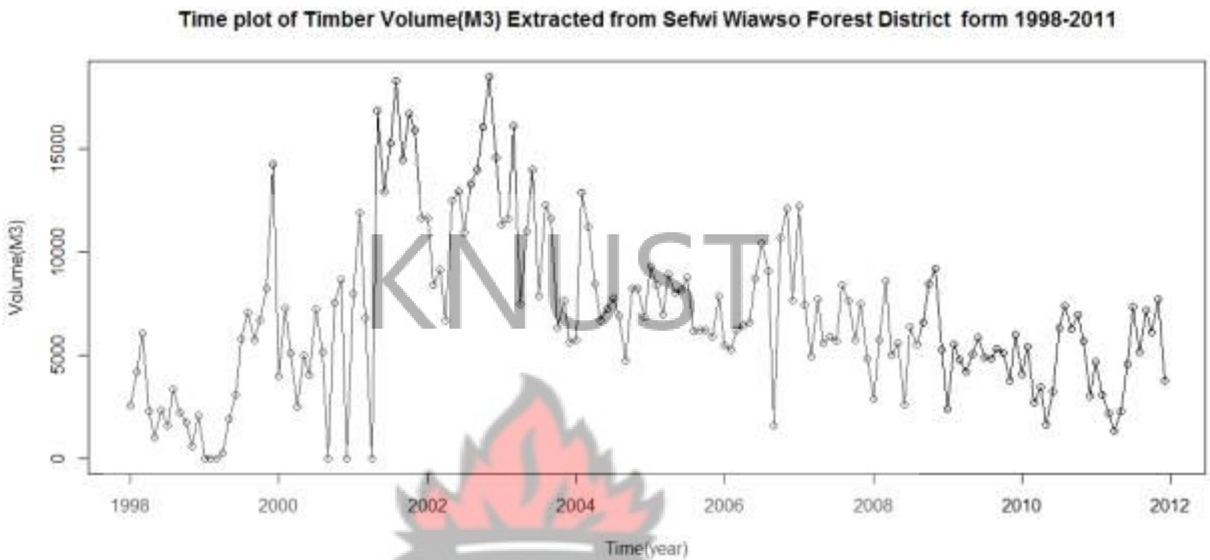


Figure 4: Time Plot Of Volume (M^3) Extracted In Ghana At Sefwi Wiawso Forest District

Figure 5 shows the time plot of volume (m^3) extracted in Ghana at Sefwi Wiawso forest district. The plot shows the pattern of volume extracted at Sefwi Wiawso forest district whether it is decreasing or increasing. These changes show a downward trend from 2002 to 2011. The trend from 2008 to 2011 indicates sustainable management practices carried in Sefwi Wiawso. From 2009 timber activities reduced, which shows Ghana's preparedness for carbon stock. For the few years, there has being some intervention like RED and RED+ which has shifted decision of extraction to conservation. For analysis and modeling purposes, a check is made whether or not consecutive years are related in some way. If so, a year's volume is then used to forecast the next year's volume. The trend in Ghana's volume (m^3) extracted in Ghana at Sefwi Wiawso forest district is mostly decreasing.

The month time plot of volume (m^3) extracted in Ghana at Sefwi Wiawso forest district in Figure 6 does not exhibit seasonal variation and it is not stationary due to the trend component.

KNUST

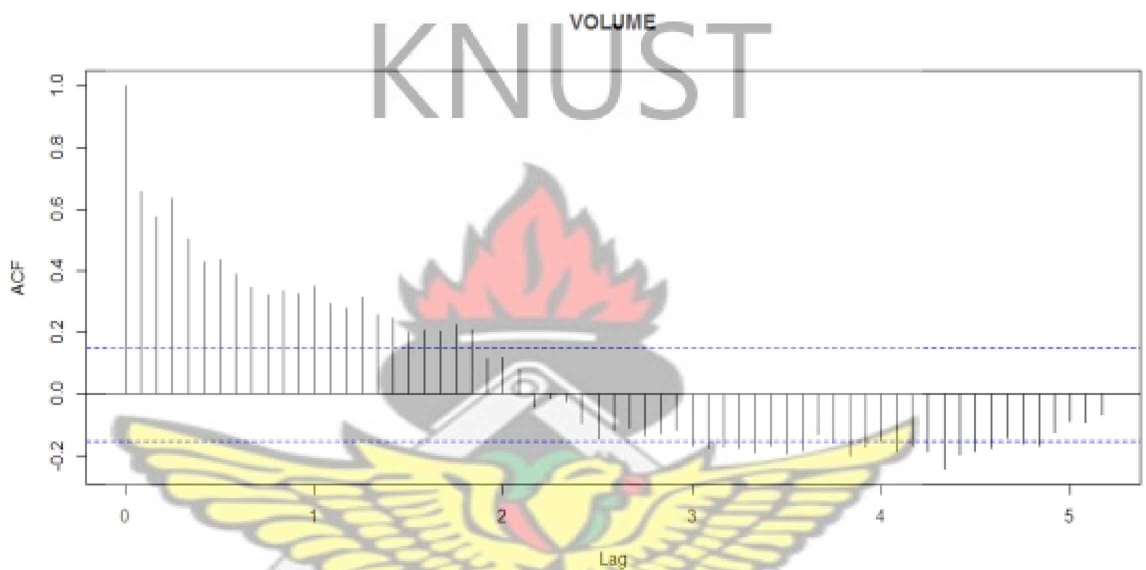


Figure 5: Autocorrelation Function Of Timber Volume (M^3) Extracted In Ghana At Sefwi Wiawso Forest District

The plot of the ACF function against the lag is called the correlogram. A trend in the data shows in the correlogram as a slow decay in the autocorrelation which depicts a downward slopping due to the exponential nature of the plot. Although we want to know about trends and seasonal patterns in the time series, we do not necessarily rely on the correlogram to identify them. The main use of the correlogram is to detect autocorrelation in the time series after we have removed an estimate of the trend and seasonal variation.

The autocorrelation function of volume (m^3) extracted in Ghana at Sefwi Wiawso forest district is shown in Figure 7 which describes the correlation between values of volume (m^3) extracted in Ghana at different points in time, as a function of the time difference. The autocorrelation function is decreasing gradually and that shows that there is a trend in the. volume (m^3) extracted in Ghana**.**

4.2 TREND DIFFERENCE

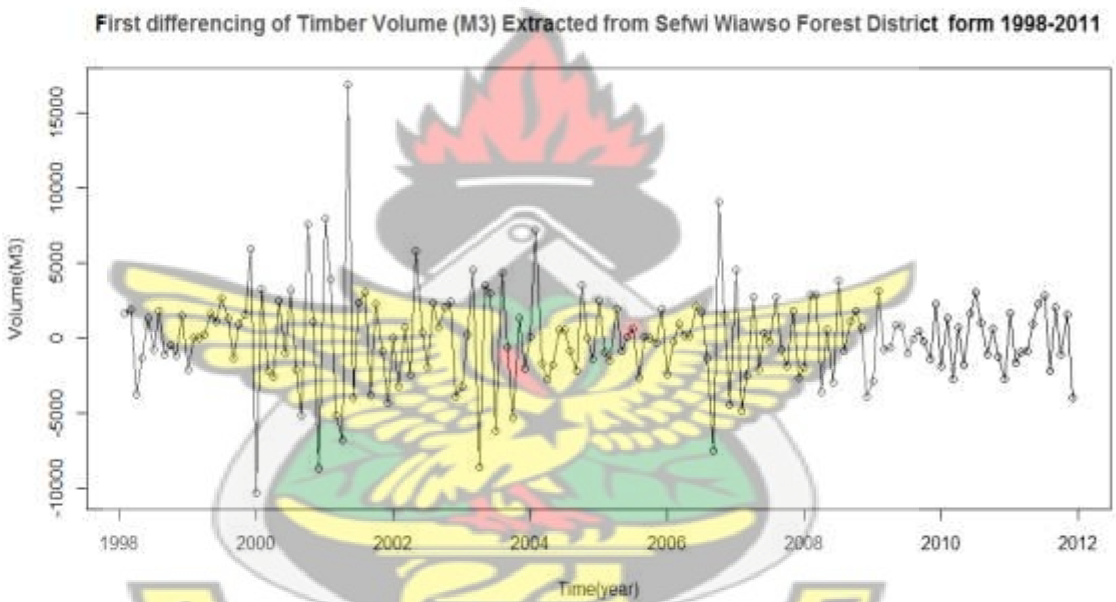


Figure 6: **First Differencing Of Timber. Extracted In Ghana At Sefwi Wiawso Forest District From 1998-2011**

To remove the trend component from the data, we difference the data. The figure 8 above is a transformation of volume (m^3) extracted in Ghana at Sefwi Wiawso forest district using first differencing method. The observation does not revert to its mean value. The transformation of the data with the first differencing displays characteristics that suggest non stationary. Due to this it is necessary to make another transformation so as to produce a new series that is more compatible with the assumption of stationarity. In general, the first difference plot in figure 8 reveal a little bit of variability. The observations move irregularly but revert to its mean value and the variability is also approximately constant. volume (m^3) extracted in Ghana at Sefwi Wiawso forest district data now looks to be approximately stable.

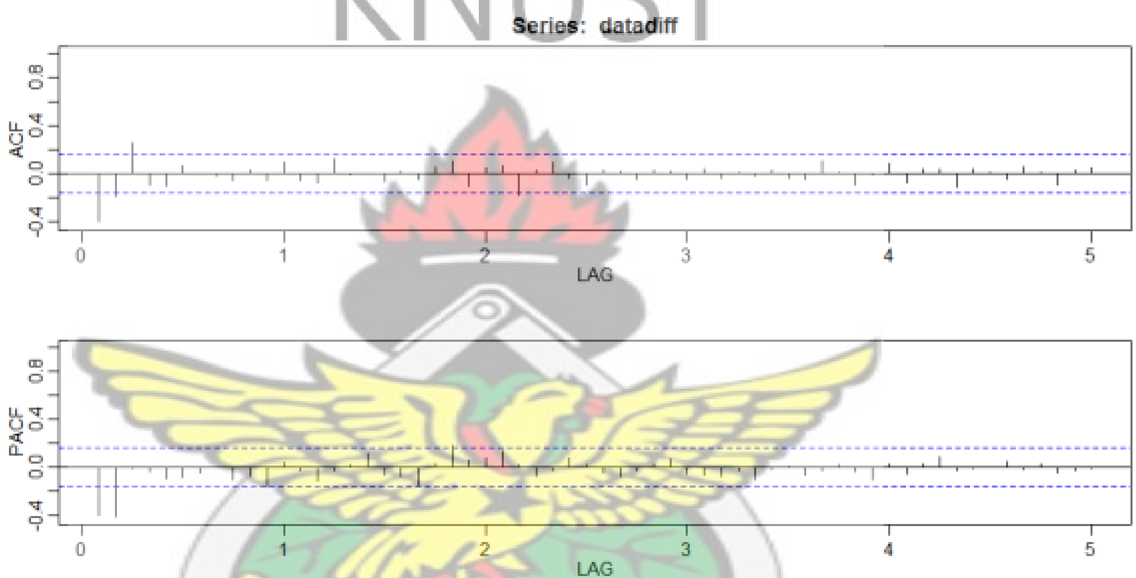


Figure 7: ACF And PACF Of The First Differencing of volume Extracted In Ghana At Sefwi Wiawso Forest District From 1998-2011

The figure 7 above shows both the autocorrelation function and the partial autocorrelation function of the first differencing of volume (m^3) extracted in Ghana at Sefwi Wiawso at various lags. Inspecting both the ACF and the PACF of the first differencing of the volume (m^3) extracted in Ghana at Sefwi Wiawso, the following models are suggested;

- ARIMA(2,1,1)

- ARIMA(2,1,0)
- ARIMA(0,1,1)

To select the best model for forecasting into the future, each model is assessed based on its parameter estimates, the corresponding diagnostics of the residuals and the AIC, BIC and AIC_c.

KNUST

4.3 MODEL SELECTION

4.3.1 PARAMETER ESTIMATES AND DIAGNOSTICS OF $ARIMA(2,1,1)$ MODEL

Series: xdata

ARIMA(2,1,1) with non-zero mean

Call: running kite

arima(x = xdata, order = c(p, d, q), seasonal = list(order = c(P, D, Q), period = S),

xreg = constant, optim.control = list(trace = trc, REPORT = 1, reltol = tol))

Coefficients:

	ar1	ar2	ma1	constant
	-0.6949	-0.4572	0.2461	1.9210
s.e.	0.1884	0.0829	0.2161	117.7547

sigma^2 estimated as 6860006: log likelihood = -1551.59, aic = 3113.19

$AIC

[1] 17.03083

$AICc

[1] 17.04633

$BIC

[1] 16.10937

Diagnostics of $ARIMA(2, 1, 1)$

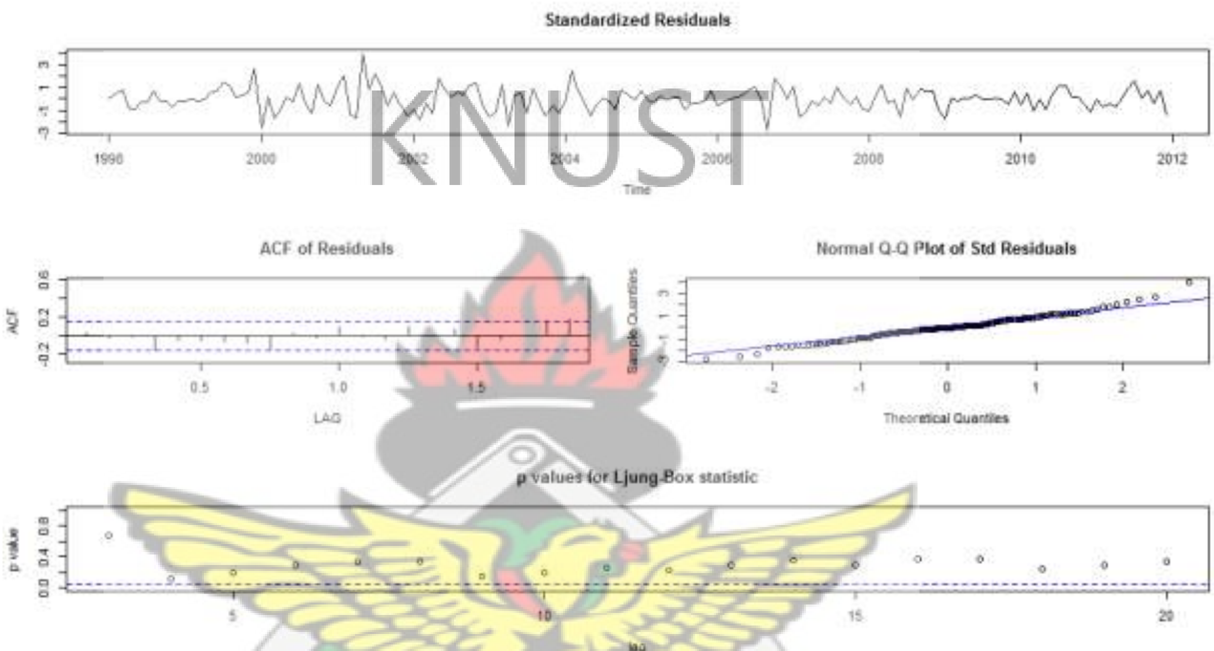


Figure 8: DIAGNOSTICS OF ARIMA $(2, 1, 1)$

(a) The standardized residuals plot in Figure 8 shows an $ARIMA(2,1,1)$ model fitted to timber volume (m^3) extracted in Ghana at Sefwi Wiawso forest district. There is an increased variation at the start of the series and a reduced variation as the series draw to the end. The plot supports the model, as no trend is present thus the standardized plot shows no obvious pattern.

(b) The plot of the ACF against the lag displays the sample ACF of the residuals from $ARIMA(2,1,1)$ model of the volume (m^3) extracted in Ghana. The dashed horizontal lines plotted are based on the large lag standard error of $\pm\frac{2}{\sqrt{n}}=\frac{2}{\sqrt{168}}\approx 0.1543$. We conclude that the plot does not show statistically significant evidence of non- zero autocorrelation in the residuals.

(c) With the normal q-q plot of the standardized residual, most of the residual seems to follow the line of best fit fairly closely except for some few outliers deviating from the normality. Since most of the residuals are located on the straight line, we can say that the normality assumption is satisfied.

(d) The plot of the Ljung- Box statistic show that the Ljung- Box p- value are all greater than 0.05. It is observed that the Ljung-Box statistics plot is not significant at any positive lag.

4.4 PARAMETER ESTIMATES AND DIAGNOSTICS OF $ARIMA(2,1,0)$ MODEL

Series: xdata

ARIMA(2,1,0) with non-zero mean

Call:

arima(x = xdata, order = c(p, d, q), seasonal = list(order = c(P, D, Q), period = S),

xreg = constant, optim.control = list(trace = trc, REPORT = 1, reltol = tol))

Coefficients:

ar1	ar2	constant
-0.4888	-0.3868	17.6584

s.e.   0.0716   0.0713 108.8732

sigma^2 estimated as 6906901: log likelihood = -1552.15, aic = 3112.3

$AIC

[1] 16.78375

$AICc

[1] 16.79711

KNUST

$BIC

[1] 15.83953

The parameter based on the t-value test is statistically significant.

DIAGNOSTICS OF $ARIMA(2,1,0)$

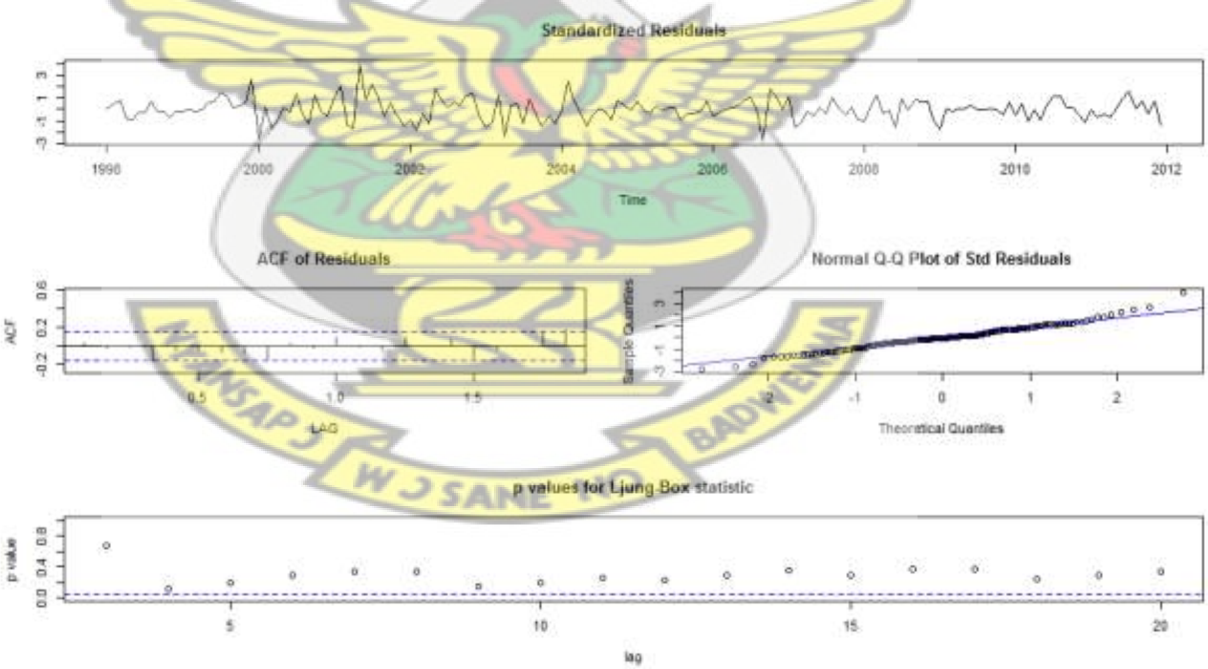


Figure 9: DIAGNOSTICS OF $ARIMA(2,1,0)$

(a) The standardized residuals plot in Figure 9 shows an $ARIMA(2,1,0)$ model fitted to timber extracted in Ghana at Sefwi Wiawso forest district. There is an increased variation at the start of the series and a reduced variation as the series draw to the end. The plot supports the model, as no trend is present thus the standardized plot shows no obvious pattern.

(b) The plot of the ACF against the lag displays the sample ACF of the residuals from $ARIMA(2,1,0)$ model of timber volume (m^3) extracted in Ghana at Sefwi Wiawso forest district of Ghana. We conclude that the plot does not show statistically significant evidence of non- zero autocorrelation in the residuals.

(c) With the normal q-q plot of the standardized residual, most of the residual seems to follow the line of best fit fairly closely except for some few outliers deviating from the normality. Since most of the residuals are located on the straight line, we can say that the normality assumption is satisfied.

(d) The plot of the Ljung- Box statistic show that the Ljung- Box p- value are all greater than 0.05. It is observed that the Ljung-Box statistics plot is not significant at any positive lag.

4.5 PARAMETER ESTIMATES AND DIAGNOSTICS OF ARIMA (0,1,1) MODEL

Call:

arima(x = xdata, order = c(p, d, q), seasonal = list(order = c(P, D, Q), period = S),
    xreg = constant, optim.control = list(trace = trc, REPORT = 1, reltol = tol))

Coefficients:

ma1 constant

-0.5708   21.4042

s.e.   0.0732   90.3416

sigma^2 estimated as 7275488: log likelihood = -1556.46, aic = 3118.92

$AIC

[1] 16.82383

$AICc

[1] 16.83661

$BIC

[1] 15.86102

KNUST

DIAGNOSTICS OF $ARIMA(0,1,1)$

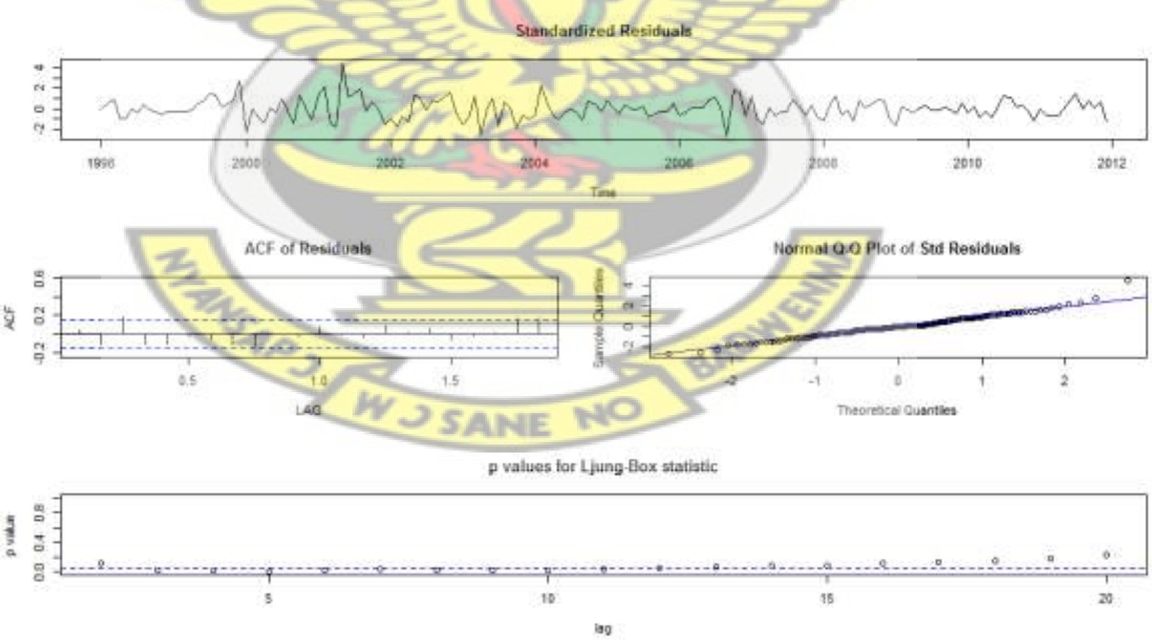


Figure 10: DIAGNOSTICS OF $ARIMA(0,1,1)$

(a) The standardized residuals plot in figure 10 shows an $ARIMA(0,1,1)$ model fitted to timber volume (m^3) extracted in Ghana at Sefwi Wiawso forest district. There is an increased variation at the start of the series and a reduced variation as the series draw to the end. The plot supports the model, as no trend is present thus the standardized plot shows no obvious pattern.

(b) The plot of the ACF against the lag displays the sample ACF of the residuals from ARIMA (0,1,1) model of timber volume (m^3) extracted in Ghana at Sefwi Wiawso forest district of Ghana. We conclude that the plot does not show statistically significant evidence of non- zero autocorrelation in the residuals.

(c) With the normal q-q plot of the standardized residual, most of the residual seems to follow the line of best fit fairly closely except for some few residuals deviating from the normality. Since most of the residuals are located on the straight line, we can say that the normality assumption is satisfied.

(d) The plot of the Ljung- Box statistic show that the Ljung- Box p- value are all greater than 0.05. It is observed that the Ljung-Box statistics plot is not significant at any positive lag.

4.6 SELECTION OF BEST MODEL FOR FORECASTING

The standardized residual plots of all the models have a constant mean and some few outliers. There is no evidence of significance in the autocorrelation functions of the residuals of all the models and the residuals appear to be normally distributed in all the models. The Ljung-Box statistics are not significant at any positive lag for all the models. The parameters in the $ARIMA(0,1,1)$ model are not significant at 5% level of significance for ar1 and ar2 which could have a negative effect on the forecast if used for prediction while the parameters in the $ARIMA(2,1,0)$ and $ARIMA(2,1,1)$ models are significant.

The $AIC, AICc$ and BIC are good for all the models but they favour $ARIMA(2,1,0)$ model.

From the above discussion it is clear that $ARIMA(2,1,0)$ model is the best model for forecasting.

KNUST

4.7 FORECASTING FOR VOLUME

Table 4.1: below show the prediction of volume for Jan. 2012 - June 2012.

6 steps prediction into the future;

Time Series:

Start = January 2012

End = June 2012

Frequency =12

sarima.for (data,6,2,1,0)

pred

	Jan	Feb	Mar	Apr	May	Jun
2012	5097.934	6002.786	5067.792	5207.930	5534.239	5353.642

se

	Jan	Feb	Mar	Apr	May	Jun
2012	2628.098	2951.556	3102.135	3509.764	3799.886	4010.054

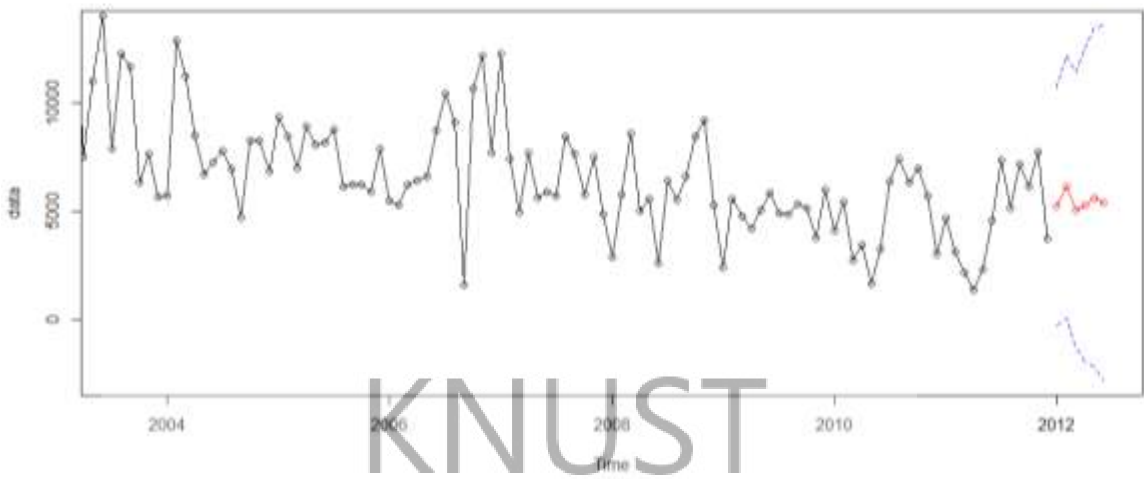


Figure 11: **Graph Of Timber Extracted In Ghana At Sefwi Wiawso Forest District From Jan. 2012- June 2012, Its Forecasts And Confidence Intervals**

Figure 11 gives the visual representation of the original timber extracted from Sefwi Wiawso data (black line), its forecasts (red line) and confidence interval (blue short dashes lines).

Time Plot Of Stem Extracted In Ghana At Sefwi Wiawso Forest District

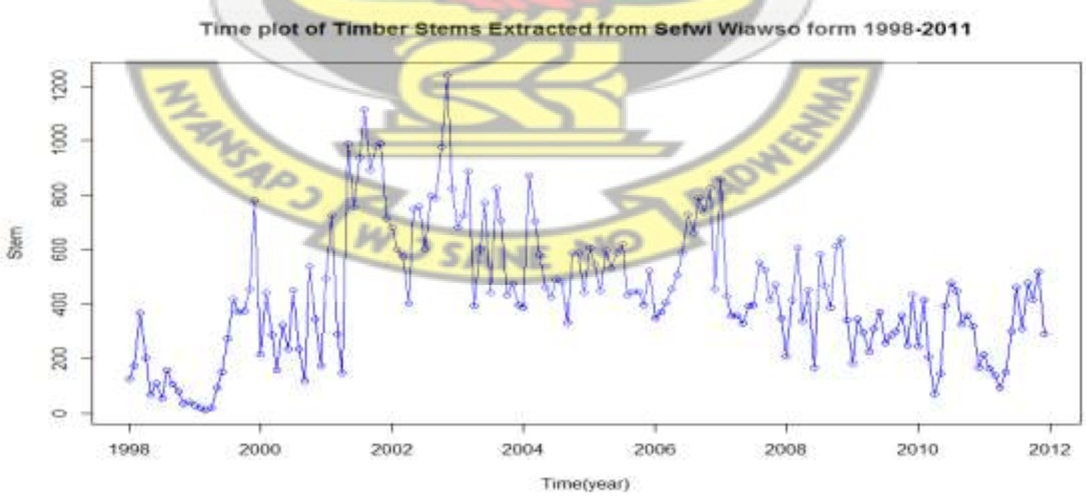


Figure 12: **Above Shows Time Plot Of Stem Extracted In Ghana At Sefwi Wiawso Forest District**

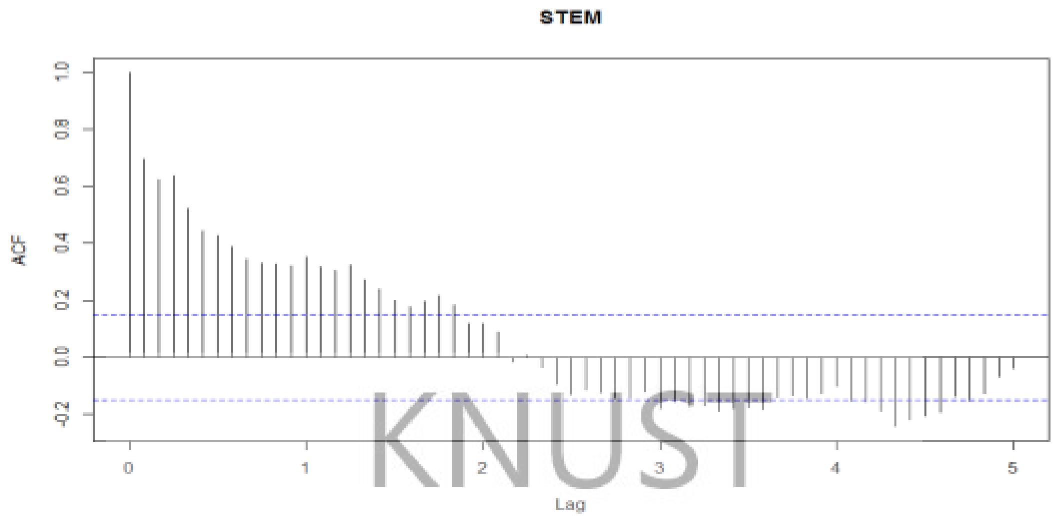


Figure 13: Autocorrelation Function Of Timber Stem Extracted In Ghana At Sefwi Wiawso Forest District

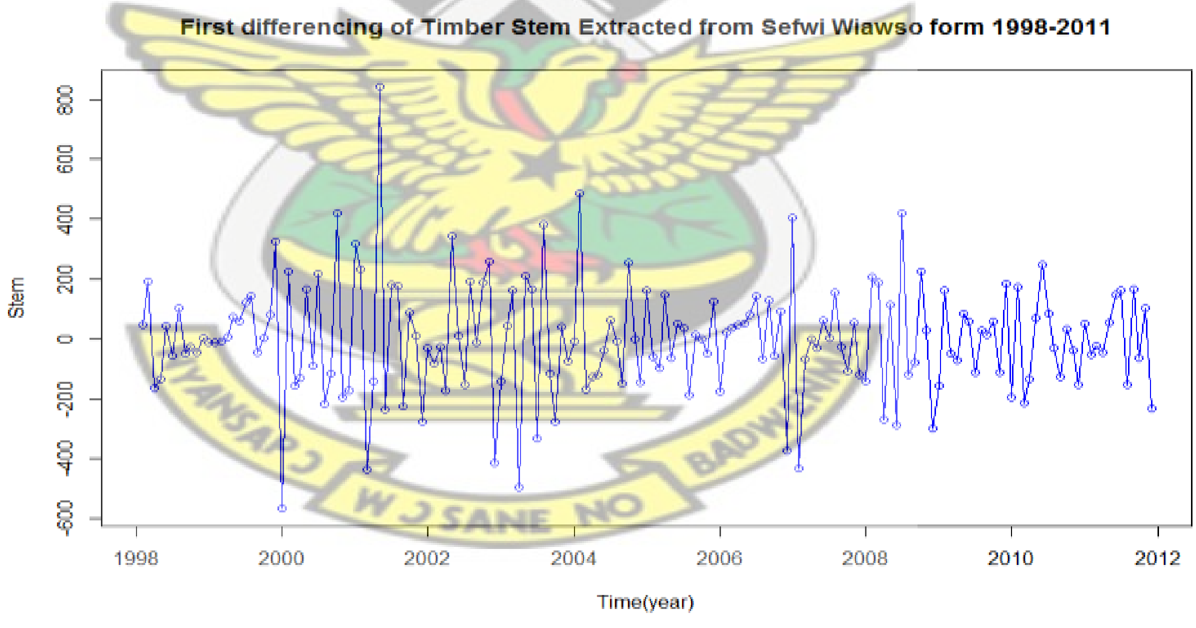
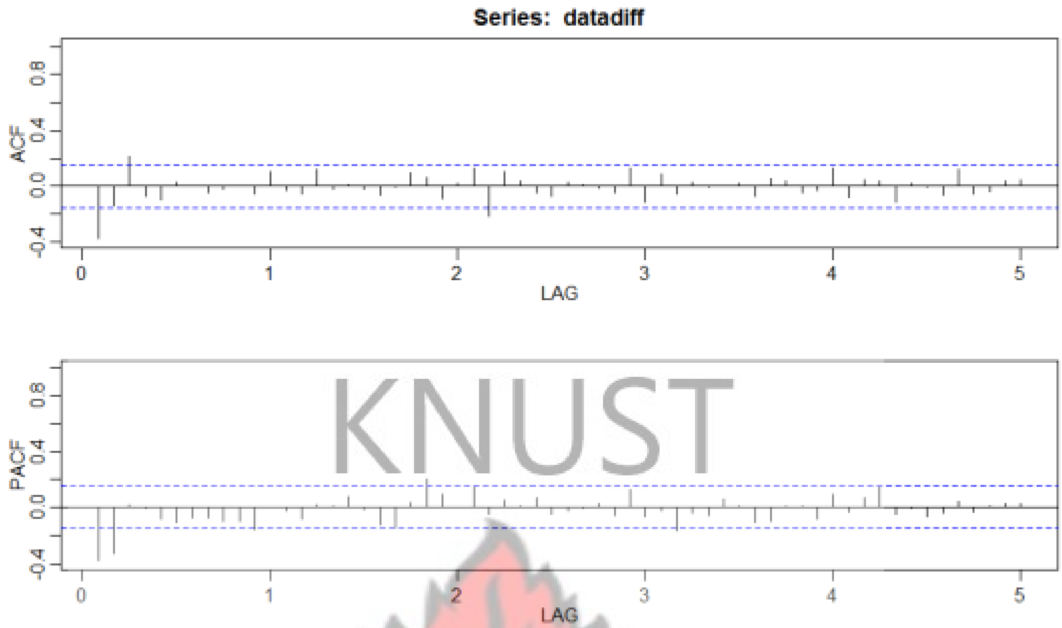


Figure 14: First Differencing Of Extracted In Ghana At Sefwi Wiawso Forest District From 1998-2011



KNUST

Figure 15: ACF And PACF Of The First Differencing of timber stem Extracted In Ghana At Sefwi Wiawso Forest District From 1998-2011

The figure 15 above shows both the autocorrelation function and the partial autocorrelation function of the first differencing of timber stems extracted in Ghana at Sefwi Wiawso at various lags. Inspecting both the ACF and the PACF of the second differencing of the timber stems extracted in Ghana at Sefwi Wiawso, the following models are suggested;

- **ARIMA(0,1,1)**
- **ARIMA(2,1,0)**
- **ARIMA(2,1,1)**

To select the best model for forecasting into the future, each model is assessed based on its parameter estimates, the corresponding diagnostics of the residuals and the AIC, BIC and AIC_c.

sarima(data,0,1,1)

```
Call:
arima(x = xdata, order = c(p, d, q), seasonal = list(order = c(P, D, Q), period = S),
    xreg = constant, optim.control = list(trace = trc, REPORT = 1, reltol = tol))
Coefficients:
         ma1  constant
      -0.5510    1.2926
s.e.   0.0726    5.8464
sigma^2 estimated as 27901:  log likelihood = -1091.88,  aic = 2189.77
$AIC
[1] 11.26021
$AICc
[1] 11.27299
$BIC
[1] 10.2974
```

KNUST

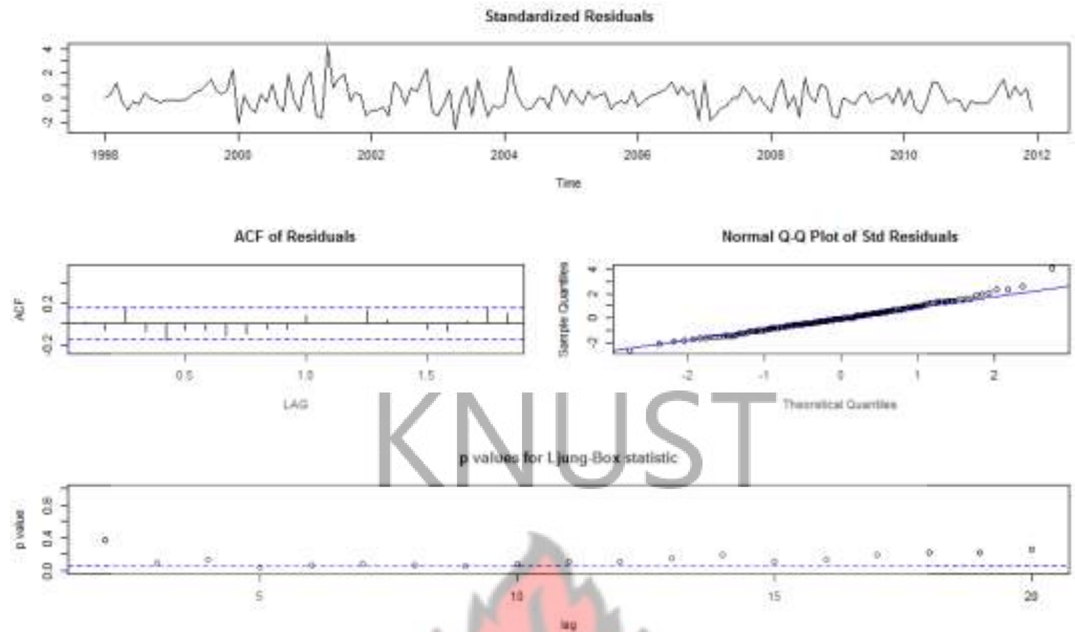


Figure 16: **DIAGNOSTICS OF ARIMA (0,1,1)**

sarima (data,2,1,0)

```
Call:
arima(x = xdata, order = c(p, d, q), seasonal = list(order = c(P, D, Q), period = S),
    xreg = constant, optim.control = list(trace = trc, REPORT = 1, reltol = tol))
Coefficients:
         ar1      ar2  constant
      -0.5063  -0.3333    1.1658
s.e.   0.0732   0.0731    6.9557
sigma^2 estimated as 27134:  log likelihood = -1089.57,  aic = 2187.14
$AIC
[1] 11.24424
```

$AICc

[1] 11.25761

$BIC

[1] 10.30003

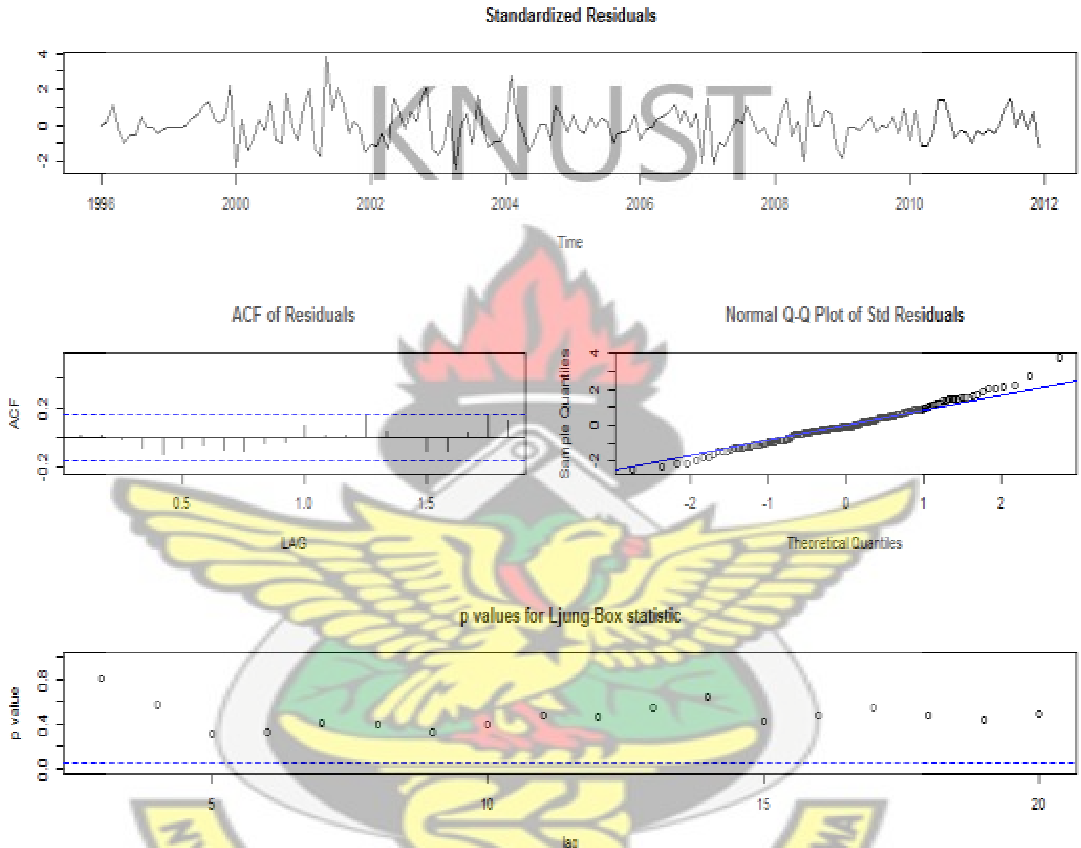


Figure 17: DIAGNOSTICS OF ARIMA(2,1,0)

sarima(data,2,1,1)

Call:

arima(x = xdata, order = c(p, d, q), seasonal = list(order = c(P, D, Q), period = S),

xreg = constant, optim.control = list(trace = trc, REPORT = 1, reltol = tol))

Coefficients:

ar1 ar2 ma1 constant

-0.5526 -0.3510 0.0522 1.0790

s.e. 0.2114 0.1026 0.2252 7.0708

sigma^2 estimated as 27125: log likelihood = -1089.54, aic = 2189.09

$AIC

[1] 11.25583

KNUST

$AICc

[1] 11.26994

$BIC

[1] 10.33021

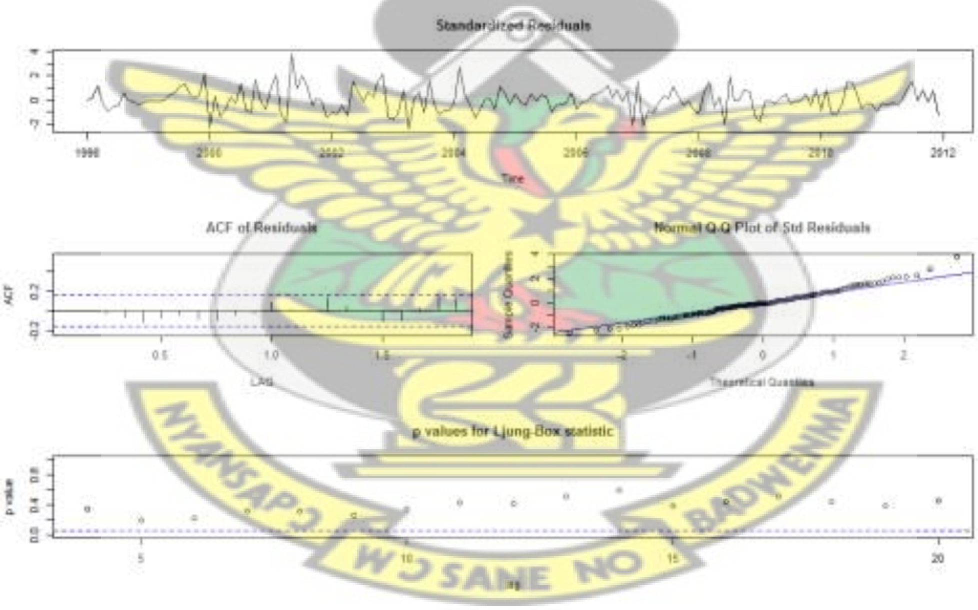


Figure 18: DIAGNOSTICS OF ARIMA (2,1,1)

4.8 MODEL SELECTION

The standardized residual plots of all the models have a constant mean and some few outliers. There is no evidence of significance in the autocorrelation functions of the residuals of all the models and the residuals appear to be normally distributed in all the models. The Ljung-Box statistics are not significant at any positive lag for all the models. The parameters in the ARIMA(0,1,1) model are not significant at 5% level of significance for ar1 and ar2 which could have a negative effect on the forecast if used for prediction while the parameters in the ARIMA(2,1,1) and ARIMA(2,1,0) models are significant.

The AIC, $AICc$ and BIC are good for all the models but they favour ARIMA (2,1,0) model.

From the above discussion it is clear that ARIMA (2,1,0) model is the best model for forecasting.

4.9 FORECASTING FOR STEMS

Table 4.2: below show the prediction of stems for Jan. 2012 - June 2012.

6 steps prediction into the future;

Time Series:

Start = January 2012

End = June 2012

Frequency =12

sarima.for(data,6,2,1,0)

$pred

	Jan	Feb	Mar	Apr	May	Jun
2012	370.7248	408.4907	360.6399	375.8821	386.3076	377.2506

$se

	Jan	Feb	Mar	Apr	May	Jun
2012	164.6963	184.1080	196.9743	223.5539	241.1020	256.0792

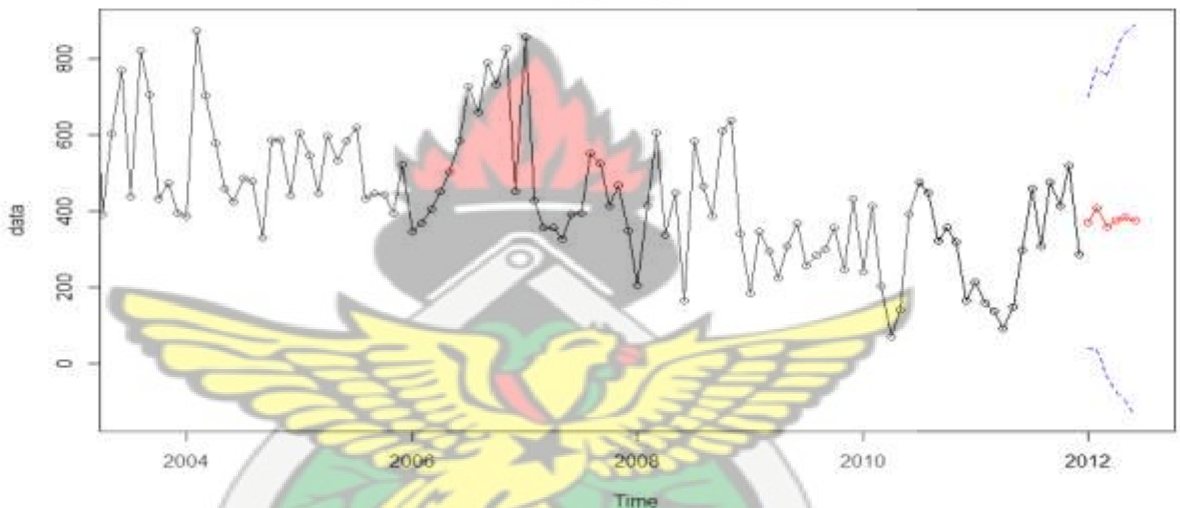


Figure 19: Graph Of Timber Stem Extracted In Ghana At Sefwi Wiawso Forest District From Jan. 2012-June 2012, Its Forecasts And Confidence Intervals

Figure 20 gives the visual representation of the original timber stems extracted from Sefwi Wiawso

Data (black line), its forecasts (red line) and confidence interval (blue short dashes lines).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.0 INTRODUCTION

This chapter describes conclusion and recommendations based on the research. The conclusion and recommendations can be used as a source of information for all stakeholders.

KNUST

5.1 CONCLUSION

It is clear from the research that Time Series analysis has shown a pattern of timber exploitation in Sefwi Wiawso Forest District and also compare the volume to the corresponding stem removed from January, 1998- December, 2011.

The model identified, ARIMA (2, 1, 0) for volume and ARIMA (2, 1, 0) for the stem show a success in attempting to forecast 6 step for both volume and stem series.

It was observed that timber extractions are gradually decreasing. This is an indication that the stocking levels in forest reserves are depleting and actions to change the trend is necessary. Sawmills can run out of resources and collapse, resulting in job and income losses to the Forestry Commission.

The model shows that there is a considerable increase in stems to volume ratio. This time, more timber stems are removed before a substantial volume could be obtained.

This is because timber operator can not obey the forty year cycle to allow the tree species to gain increased volume before it is harvested.

5.2 RECOMMENDATIONS

As a starting point, the Forestry Commission should discourage sawmills and timber operators from removing undersized trees based on the result from this research. This should serve as a guarantee to all stakeholders to ensure sustainable management of the state resource.

FC should provide strong based forest protection measures in other to curve illegalities which include farming and chain sawing.

The result obtained from this research should serve as a guide to investigate the trend of tree stems and volumes periodically. It is further recommended for FC to adopt the model to estimate timber values periodically in monetary terms.

The trend from this work shows that stocking levels are going down. Therefore all stakeholders in forestry should rethink the best way to restock the forest reserves in the country so that exploitation of timber will not come to a halt and also conduct more research for the promotion and usage of lesser known species.

KNUST
NYANSAPO W J SANE NO BADWEMA

REFERENCES

Adam, K.A. (2003). Review of regulatory mechanisms in selective logging. ITTO/FORIG.

Agyeman, D.J. (1991). Culture and location of the Akan people. Pioneer No. 11161. Kumasi.

Agyeman, V. K., C. Turnbull & M. D. Swaine. (1995). Maintenance of biodiversity in the tropical high forests: current research initiatives in Ghana. Abstract: Proc. 10 IUFRO world congress. Pp. 76-77.

Alvarez-Buylla, E. R. & M. Martinez Ramos. (1990). Seed bank versus seed rain in the regeneration of a tropical pioneer tree. Oecologia 84:314-325.

Anderson, R. H. (2003). fixed Broadband Wireless System Design, 1st Edition, Chichester: John Wiley & Sons, ISBN 0-470-84438-8

Appanah, S. & A. M. Mohd. -Rasol. (1995). Dipterocarp fruit dispersal and seedling distribution. Journal of Tropical Forest Science 8: 258-263.

Appiah, S.K., Siisi-Wilson, E., Agyeman, V.K., Ortsin, G. And Birikorang, G. (1998). Ecological impact of increased harvesting of lesser-used species (lus). ITTO PD 33/95. Report submitted to the Internation Tropical Timber Organisation (ITTO), Yokohama, Japan. 53 pp.

Beeko, C. (2005). Validation of legal timber and sustainable forest management in Ghana. Paper presented at Restoration and sustainable management of forests in Ghana, Tropenbos International–Ghana conference, July 5 – 7. 2005. Elmina, Ghana.

Birikorang, G., Okai, R., Asenso-Okyere, K., Afrane, S. and Robinson, G. (2001). Ghana Wood Industry and Log Export Ban Study (final report). DFID, London. 53 pp.

Birikorang, G. (2004). Environmental policy evaluation – Paper prepared as input into Preparation of Ghana's Poverty Reduction Strategy Credit (2).

Boakye, K.A and Affum-Baffoe K., (2006)Trends In Forest Ownership, Forest Resource Tenure And Institutional Arrangements Case Study From Ghana, Resource Management Support Centre, Forestry Commission of Ghana.

Brockwell, P.J and Davis, R.A. (2002), Introduction to Time Series and Forecasting (second edition), Springer texts in Statistics.

Chazdon, R. And Fetcher, N. (1984). Photosynthetic light environments in a lowland tropical rain forest in Costa Rica. Journal of Ecology 72:553-564.

Corbasson, M. and Souvannavong, O. (1988). Terminalia superba Engl. & Diels: current research on biology, physiology and breeding of Terminalia superba. Informations sur les Ressources Genetiques Forestieres (FAO) 16: 29-34.

Davies J. (2003). Stocks and flows: a comparative analysis of the 1989 and 2001 forest reserve inventories and log production data. What price sustainability?

Denslow, J.S. (1984). Influence of disturbance on species diversity: reply to T.C. Whitmore. Biotropical16:239-240.

Eyo, O. E., Menkiti, A. I., and Udo, S. O.(2002). Microwave Signal Attenuation in Harmattan Weather Along Calabar-Akampkpa Line-of-Sight Link. Department of Physics, University of Calabar, Calabar-NIGERIA

FC Annual Report, (2008).

FC Annual Report, (2009).

FC MoP (1995), *Study guide* , Forestry Commission, RMSC.

Ghartey, K. K. F. (1992). The evolution of forest management in the Tropical High Forest of Ghana. Paper presented at conference sur la conservation et utilisation rationelle de la foret dense d'Afrique centrale et de l'ouest. World Bank/ADP/IUCN Abidjan, Ivory Coast.

Hartshorn, G. S. (1978). Tree falls and tropical forest dynamics. In: P. B. and Zimmermann, M. H. (eds.) Tropical Trees as Living Systems. Tomlinson, Cambridge University Press, U. K.

Hawthorne, W. D. (1993). Forest regeneration after logging: findings of a study in the Bia South Game Production Reserve, Ghana. ODA Forestry Series 3. Natural Resources Institute, Chatham.

Ho, C. (2005). Modeling and Simulation for Realistic Realistic Propagation Environments of Communications Signals at SHF Band, Annual ITEA Technology Review Conference, Atlanta, Georgia.

ITTO report (1992) Trend of wood supply and demand, Country report- Japan, produced by Forestry Department.

ITTO. (2001). Market report, 1st to 15th July. ITTO, Yokohama, Japan.

Jans, L. , L. Poorter, R. S. A. R. Van Rompaey & F. Bongers. (1993). Gaps survey and forest zones in tropical moist forest in Ivory Coast. Biotropica 25: 258-269.

Jesse N. And Yangdong P. (2005). Diatom assemblages as indicators of timber harvest effects in coastal Oregon stream.

Lowe, R. G. (1984). The regeneration and growth of ABURA: Mitragyna stipulosa (DC) O. Kuntze and Mitragyna ciliata Aubr. & Pellegr. Fed. Dept. of Forest Research, Ibaden. Technical Note 27

Makridakis, S., Wheelwright, S., and McGee, V., (1983), Forecasting Methods and Applications (2nd Edition), Wiley and Sons, New York.

MLFM Publication (2011).

McDowell, G. (2005). Sealaska Timber Harvest Employment Impacts, Alaska Department of Labor and Workforce Development.

Schulze, J.P. (1960). Ecological studies on rain forests in Northern Surinam. (The vegetation of Surinam (II) Van Eedenfonds, Amsterdam, The Netherlands.

Sundquist, D., and Birnie, R. (2008). North Country Timber Harvest Trends Study, A Project of the Society for the Protection of New Hampshire Forests, Forest Research Department.

Shumway, R.H. and Stoffer, D.S (2000) Time Series Analysis and Its Applications, Springer Verlag, New York,.

Swaine, M. D. & Whitmore, T. C. (1988). On the definition of ecological species groups in tropical rain forests Vegetation. 75: 81-86.

Swaine, M. D, Agyeman, V. K. & Adam, A. R. (1998). Tree regeneration after logging in two forest reserves in Ghana. Paper presented at the International Conference on Value-Added Processing and Utilisation of Lesser-Used Timber Species. , 17th-19th February, 1998, Kumasi, Ghana.

KNUST

Tongass National Forest. (1997). Final Environmental Impact Statement, Tongass National Forest Land Management Plan Revision. www.fs.fed.us/r10/TLMP/FEIS/FEIS_COV.PDF

World Bank. 2005. Ghana: natural resources management and growth sustainability. Draft report. World Bank/DFID/ISSER, Ghana. 209 pp.

Whitmore, T.C. (1990). An introduction to tropical rain forests. Claredon Press, Oxford, UK 226 pp.

Yantai, S., Minfang. Y., Oliver, Y., Jiankun, L. and Huifang, F. (2005). Wireless traffic modeling and Prediction using seasonal ARIMA models. The Institute of Electronics, Information and Communication

KNUST

APPENDIX I: R codes

```
library (Rcmdr)
data=ts(swv,start=1998,freq=12)
plot(data,main="Time plot of Timber Volume Extracted from Sefwi Wiawso form
1998-2011",xlab="Time(year)",ylab="Volume(M3)",type="o")

 acf(data,62)
 library(forecast)
 ndiffs(data)
[1] 1
 nsdiffs(data)
[1] 0
Auto.arima(data)
library(tseries)
 kpss.test(data)

        KPSS Test for Level Stationarity

data:  data
KPSS Level = 0.7156, Truncation lag parameter = 2, p-value = 0.01213
datadiff=diff(data)
plot(datadiff,main="First differencing of Timber Volume Extracted from Sefwi Wiawso
form 1998-2011",xlab="Time(year)",ylab="Volume(M3)",type="o")

 load("C:\\Users\\Rockson\\Desktop\\PROJECTTODAY\\tsa3.rda")
 acf2(datadiff,60)
sarima(data,2,1,1)
sarima(data,2,1,0)
sarima(data,0,1,1)
sarima.for(data,6,2,1,0)
```

KNUST
NYANSAPO WO SANE NO BADWENMA

APPENDIX II

R-CODE FOR STEM

```
library(Rcmdr)
data=ts(stem,start=1998,freq=12)
plot(data,main="Time plot of Timber Stems Extracted from Sefwi Wiawso form 1998-2011",xlab="Time(year)",ylab="Stem", type="o",col="blue")
acf(data,60)
 library(forecast)
 ndiffs(data)
[1] 1
 nsdiffs(data)
[1] 0

Auto.arima(data)
library(tseries)
 kpss.test(data)

        KPSS Test for Level Stationarity

data:  data
KPSS Level = 0.7156, Truncation lag parameter = 2, p-value = 0.01213
datadiff=diff(data)
plot(datadiff,main="First differencing of Timber Stem Extracted from Sefwi Wiawso form 1998-2011",xlab="Time(year)",ylab="Stem",type="o",col="blue")
load("C:\\Users\\Rockson\\Desktop\\PROJECTTODAY\\tsa3.rda")
 acf2(datadiff,60)

sarima(data,0,1,1)
sarima(data,2,1,1)
sarima(data,2,1,0)
sarima.for(data,6,2,1,0)
```

KNUST
W J SANE NO BADWENMA

APPENDIX III

LIST OF CLASS I, II & III NATURAL FOREST SPECIES IN GHANA

CLASS NAME / MEANING	SCIENTIFIC NAME	COMMON NAME
CLASS I SPECIES (These are species of major economic importance)	*Chlorophora excelsa*	Odum
	Entandrophragma angolense	Adinam
	Entandrophragma cylindricum	Sapela
	Entandrophragma utile	Utile
	Khaya anthotheca	Krumben
	Khaya grandifoliola	Mahogany (Kroba)
	Khaya ivorensis	Mahogany (Dubini)
	Tieghemella heckelli	Baku
	Nauclea diderrichii	Kusia
	Afromosia elata	Kokrodua
	Lovoa klaineana	Dubinibriri
	Terminalia ivorensis	Emeri
	Triplochiton scleroxylon	Wawa
	Tarrietia utilis	Nyankom
CLASS II SPECIES (These are species of lesser economic importance)	*Entandrophragma candollei*	Ceida Kokoti
	Guarea cedrata	Kwabohoro
	Guarea thompsonii	Kwabohoronini
	Lophira alata	Kaku
	Piptadeniastrum africanum	Dahoma
	Antiaris toxicaria	Kyenkyen
	Mansonia altissima	Mansonia
	Mitragyna ciliate	Subaha
	Mitragyna stipulosa	Subahakoa
	Nesogordonia papaverifera	Danta
	Turraeanthus africanus	Apapaye

CLASS III SPECIES (These are species of possible future economic importance)	*Albizia adianthifolia*	Penpina
	Albizia ferruginea	Awienpoosamina
	Albizia zygia	Okoro
	Afzelia africana	Papoa
	Anopyxis klaineana	Kokote
	Canariun schweinfurthii	Bediwonua
	Celtis adolfi-friderici	Celtis / Esakosua
	Celtis zenkeri	Celtis / Esakokoo
	Combretodendron africanum	Esia
	Cylicodiscus gabunensis	Denya
	Cynometra ananta	Ananta
	Diospyros sanza-minika	Sanza-minika
	Distemonanthus benthamianus	Bonsamdua
	Erythrophleum guineense	Potrodum
	Holoptelea grandis	Nakwa
	Mammea africana	Bompagya
	Pycnanthus angolensis	Otie
	Scottellia chevalierii	Tiabutuo
	Sterculia rhinopetala	Wawabima
	Strombosia glaucescens	Afena
	Terminalia superba	Ofram

KNUST
NYANSAPƆ WƆSANE NO BADWEMMA

APPENDIX IV

Timber
Volume Extracted From Sefwi Wiaso Forest District

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	2520.73	623.358	3956.61	7987.88	11625.09	11355	5718.06	9321.43	5459.41	12251.76	2862.5	2372.95	4099.17	4675.62
February	4193.13	415.572	7266.94	11928.34	8408.19	11575.4	12896.57	8425.14	5272.1	7422.06	5725.01	5546.07	5418.88	,080.99
March	6048.03	207.786	5090.03	4528.38	9125.79	16107.1	11207.11	6955.151	6240.78	4946.14	8589.41	4766.57	2709.44	2166.11
April	2285.45	243.98	2500.97	2264.2	6705.74	7515.91	8461.86	8923.42	6418.22	7689.75	4994.35	4172.45	3445.99	1338.87
May	980.23	1925.02	5005.45	16882.56	12506.73	11007.4	6691.89	8045.11	6577.12	5597.54	5572.29	5045.52	1629.27	2278.4
June	2352.21	3061.21	4009.17	12918.2	12926.32	14019.8	7235.97	8169.61	8715.93	5884.34	2573.42	5853.54	3258.54	4556.8
July	1562.76	5765.41	7235.16	15250.38	10948.7	7855.59	7760.1	8785.62	10419.68	5685.89	6401.42	4876.83	6347.08	7350.78
August	3359.18	7083.78	5151.73	18319.2	13285.69	12267.9	6909.48	6142.31	9077.87	8426.5	5517.63	4825.98	7384.66	5144.96
September	2237.12	5727.09	1717.24	14490.53	14008.79	11627.9	4702.2	6237.29	1589.21	7629.93	6608.23	5333.33	6295.28	7,186.42
October	1740.92	6678.99	7553.65	16728.4	16076.78	6326.58	8253.16	6212.42	10671.75	5728.35	8453.53	5118.83	6965.29	,119.85
November	586.99	8251.94	5763.52	15899.01	18515.79	7631	8253.16	5890.12	12145.61	7509.17	9193.65	3754.53	5707.16	7709.77
December	831.144	14239.74	2881.77	11629.95	14582.08	5639.76	6831.87	7851.71	7671.13	4839.72	5268.54	6004.5	3016.45	3738.7

APPENDIX V

Stem Extracted From Sefwi Wiaso Forest District

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
January	125	29	214	493	681	682	388	606	348	859	208	184	243	216
February	174	19	442	725	600	726	873	546	370	427	415	346	416	162
March	367	10	285	288	575	888	705	448	406	358	606	297	205	138
April	202	18	156	146	402	392	580	598	453	358	338	226	71	93
May	67	92	323	988	749	604	461	533	505	329	451	310	143	149
June	110	152	234	754	758	772	425	586	586	393	165	370	393	299
July	52	274	452	936	604	440	489	621	729	396	585	258	478	461
August	156	418	236	1115	798	824	480	433	661	553	467	286	449	310
September	106	372	119	890	788	707	330	446	791	525	387	300	324	477
October	79	375	538	978	976	433	587	445	735	416	612	359	357	415
November	34	456	345	988	1236	473	587	396	827	470	640	248	320	520
December	39	781	173	713	823	397	442	523	453	349	341	435	166	288

KNUST