Wisdom at the source of the Blue Nile

Volume 5: Number 1
April, 2020

# Journal of Agriculture and Environmental Sciences (JAES)

Publication of the College of Agriculture and Environmental Sciences
Bahir Dar University, Ethiopia
http://www.bdu.edu.et/caes
ISSN: 2616-3721 (Online); 2616-3713 (Print)

# Re-Directing African Cocoa Bean Export Performance in the Face of Global Cocoa Trade

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Received: August 31, 2019 Accepted: February 20, 2020

**Abstract:** *The performance of African cocoa in the global market has not been impressive with ample gain been lost despite its exportation lead position in the world. It is against this background that the present research looks into the possibility of re-directing the African cocoa export in the global market in order to increase its gain due to its position as the largest exporter of the product in the world. Annual time series data which covered cocoa export and import both in physical and monetary terms for the World, Africa, other continents and macro-economic indicators sourced from the FAO and UNCTAD data banks spanning from 1991 to 2017 were used. The data were analyzed using both descriptive and inferential statistics. Evidenced showed that African cocoa has competitive advantage and its geographical trade concentration can be increase if the continent increases its current export by 41.73%, thus spurring an export value gain of 40.82% over the current average export value recorded for the study period. Furthermore, it was observed that the African cocoa exporters respond to any innovation that induced deviation from the equilibrium in a manner that the current export quantity of cocoa will converge towards the equilibrium. The major factor affecting export decision cum export performance of African cocoa in the global cocoa trade market is the price factor. Therefore, the regional bloc organization (AU) and the major exporting economies should checkmate the oligopsony power of the importing countries through pricing efficiency. In addition, there is a need to enhance the quality of the product too.*

**Keywords:** African export, Cocoa bean, Cocoa trade, Global market



## 1. Introduction

The trade theories succinctly advocated that nations should specialize in the production and exportation of those commodities they have comparative advantage among the comity of nations. African has taken the comparative advantage of being the largest producer and exporter of cocoa bean accounting for almost 70% of the total world export for almost a decade (FAOSTAT, 2018). Agricultural trade has been identified as one of the key drivers of economic growth and development in developing countries that are willing to take advantage of the trade liberalization in the era of globalization.

Africa for a while now has not been getting remunerative returns in the global cocoa trade due to some challenges, which ranges from quality standard, collusive effect of oligopolistic intermediaries, oligopsony power of importing economies etc. The poor performance of this commodity in the international market has spurred many researchers across the sub-Saharan Africa to evaluate the performance of the commodity. However, the crux is that all the research works limited their scope to individual economies (Syrovatka and Darkwah, 2008; Syrovatka, 2009; Ndubuto *et al.*, 2010; Daramola, 2011; Amoro and Shen, 2013; Okon and Ajene, 2014; Verter and Bečvařova, 2014 a, b; Verter, 2016) rather than studying the export performance from the perspective of the African economy as a whole. This is because the continent maintains a lead in both production and exportation of cocoa in the world. In addition, none of the documented studies makes an empirical attempt in re-directing export performance of cocoa even at the individual economies more or less African economy as an entity.

Evidence from FAOSTAT (2018) showed that the global production of cocoa bean has been on the increase from 1.2 million MT in 1961 to 4.6million MT in 2013 while the export maintained a rise from 1.03 million MT in the year 1961 to 3.04 million MT in the year 2004, and thereafter plummeted to 2.73 million MT in 2013. However, the production and export trend of African cocoa bean has been exhibiting an oscillating swing (up and downswings) more than six decades. This performance is largely due to the high demand for the crop by the consuming economies, especially North America and Europe, and recently the emerging economies e.g. China, India and Malaysia. In the light of the above challenges this study aimed at looking into the possibility of re-directing export performance of African cocoa bean empirically and suggesting the way forward for the commodity in the global trade.

## 2. Research Methodology

Annual time series data, which covered cocoa export, and import both in physical and monetary terms for the World, Africa, other continents and macro-economic indicators sourced from the FAO and UNCTAD data banks spanning from 1991 to 2017 were used. The data were analyzed using descriptive statistics, growth model, instability index, Gini coefficient index in conjunction with Lorenz curve, simulation model (Linear programming Algorithm), unit root tests and Engel-Granger two step procedures.

### *Empirical model*

**Growth rate**: The compound annual growth rate was calculated using the exponential model given below:

$$\gamma = \alpha\beta^t \quad [1]$$

$$ln\gamma = ln\alpha + tln\beta \quad [2]$$

$$CAGR = [Antilog\beta - 1] \times 100 \quad [3]$$

Where,

CAGR = Compound growth rate

*t* = time period in year

$\gamma$ = export quantity/value

$\alpha$ = intercept

$\beta$ = estimated parameter coefficient

**Instability index:** The simple coefficient of variation (CV) over-estimates the level of instability in time series data characterized by long-term trends, whereas the Cuddy-Della Valle Index corrects the coefficient of variation by instability index which is given below.

$$II = CV*(1-R^2)^{0.5} \quad [4]$$

Where,

II = the Instability index;

CV = Coefficient of Variation; and,

$R^2$ = Coefficient of multiple determinations

The instability index was classified as low instability (≤ 20%) and high instability (> 20%).

**Gini coefficient index**: The Gini coefficient index is defined as a ratio of the areas on the Lorenz curve and the formula is given as:

$$G = A/0.5 = 2A=1-2B \quad [5]$$

If the area between the line of perfect equality and Lorenz curve is A, and the area under the Lorenz curve is B, then the Gini index G =A/ (A+B), since A +B = 0.5

Where,

A = 0.25

B = 0.25

**Linear programming model**: The linear programming model is given as follows:

$$\text{Maximize } Z = \sum_{i=1}^{n} P_i * Q_i \quad [6]$$

Subject to

$$\sum_{i=1}^{n} Q_i \leq b_i \quad [7]$$

$$\sum_{i=1}^{n} P_i * Q_i \ and\ Q_i \geq 0;$$

Where,

Z = total export value of cocoa from Africa

$P_i$ = unit price ($/ton) of exported cocoa from Africa to continent *i*

$Q_i$ = quantity in tons of exported cocoa from Africa to continent *i*

$b_i$ = maximum quantity of exported cocoa from Africa to continent *I*, and

*i* = number of importing continents

**Augmented Dickey Fuller Test**

Following Blay *et al.* (2015), Singh *et al.* (2016) and Sadiq *et al.* (2016) the Augmented Dickey-Fuller test (ADF) used as indicated below:

$$\Delta P_t = \alpha + P_{t-1} + \sum_{j=2}^{it} \beta_i \Delta P_{it-j+t} + \varepsilon \quad [8]$$

Where,

$P_{it}$= the $i^{th}$ variable at the time $t$,

$\Delta P_{it}(P_{it} - P_{t-1})$ *and* $\alpha$ = intercept or trend term

**Engel-Granger two-step procedure model:**

***Long-run dynamic model:***

$EXPQ_t = \beta_0 + \beta_1 TOP_{t-1} + \beta_2 CPQ_{t-1} + \beta_3 EXR_{t-1} + \beta_4 INF_{t-1} + \beta_5 AMGDP_{t-1} + \beta_6 ASGDP_{t-1} + \beta_7 WP_{t-1} + \beta_8 AC_{t-1} + \beta_9 DFI_{t-1} + \beta_{10} EXPQ_{t-1} + \varepsilon_i$ [9]

***Short-run dynamic model:***

$\Delta EXPQ_t = \beta_0 + \beta_1 \Delta TOP_{t-1} + \beta_2 \Delta CPQ_{t-1} + \beta_3 \Delta EXR_{t-1} + \beta_4 \Delta INF_{t-1} + \beta_5 \Delta AMGDP_{t-1} + \beta_6 \Delta ASGDP_{t-1} + \beta_7 \Delta WP_{t-1} + \beta_8 \Delta ACt_{-1} + \beta_9 \Delta DFI_{t-1} + \beta_{10} \Delta EXPQ_{t-1} + \varepsilon_i$ [10]

Where,

EXPQ = Export quantity of cocoa bean
TOP = Trade openness
CPQ = Cocoa production quantity
EXR = Exchange rate
INF = Inflation rate
AMGDP = America-GDP
ASGDP = Asia-GDP
EGDP = Europe-GDP
WP = World price of cocoa bean
AC = Agriculture credit
DFI = Direct foreign investment
$\varepsilon_i$ = error term
$t$ = current time
$t$-$1$ = one year lagged period
$\beta_0$ = the intercept
$\beta_{1-n}$ = parameter estimates, and
$\Delta$ = first difference operator.

## 3. Results and Discussion

### 3.1. Export trend of African cocoa

The results showed that cocoa export exhibited an oscillating trend during the period 1991 to 2017 with the least ebb quantity exported been 1.06 million MT in the year 1992, representing 86.04% of the base year and the maximum peak exported been 2.407 million MT in the year 2011 representing 195.05% of the base year (Table 1a and Figure 1). Similar results were observed for the export value across the study period. Furthermore, the quantity of cocoa exported and export revenue generated during the stipulated period increased by 33,661.2 tons annually, representing 1.9% of the average quantity of African cocoa export; and increased by $1.27 billion annually, representing 4.31%of the average African cocoa export revenue during the study period (Table 1b).

**Table 1a: Africa export trend of cocoa bean during 1991-2017**

| Year | Export quantity | | $/ton | | Export value ($) | |
|---|---|---|---|---|---|---|
| | Qty (MMT) | Index | $ | Index | Billion $ | Index |
| 1991 | 1.234277 | 100 | 1036.062 | 100 | 1.278787 | 100 |
| 1992 | 1.062014 | 86.04341 | 1065.493 | 102.8407 | 1.131569 | 88.48768 |
| 1993 | 1.330621 | 107.8057 | 952.7717 | 91.96091 | 1.267778 | 99.13911 |
| 1994 | 1.185363 | 96.03703 | 1162.096 | 112.1648 | 1.377506 | 107.7197 |
| 1995 | 1.247838 | 101.0987 | 1372.08 | 132.4323 | 1.712134 | 133.8873 |
| 1996 | 1.820253 | 147.4752 | 1335.758 | 128.9265 | 2.431417 | 190.1346 |
| 1997 | 1.498198 | 121.3826 | 1339.14 | 129.2529 | 2.006297 | 156.8906 |
| 1998 | 1.450554 | 117.5226 | 1509.707 | 145.7159 | 2.189911 | 171.2491 |
| 1999 | 1.728752 | 140.0619 | 1246.659 | 120.3268 | 2.155165 | 168.532 |
| 2000 | 1.723118 | 139.6055 | 910.4223 | 87.87337 | 1.568765 | 122.676 |
| 2001 | 1.67428 | 135.6486 | 1051.846 | 101.5235 | 1.761084 | 137.7152 |
| 2002 | 1.651453 | 133.7992 | 1647.91 | 159.0552 | 2.721446 | 212.8146 |
| 2003 | 1.684471 | 136.4743 | 1822.613 | 175.9175 | 3.070139 | 240.0821 |
| 2004 | 2.193099 | 177.6829 | 1404.451 | 135.5567 | 3.080101 | 240.8611 |
| 2005 | 2.04234 | 165.4685 | 1470.217 | 141.9044 | 3.002683 | 234.8071 |
| 2006 | 1.997086 | 161.8021 | 1594.432 | 153.8936 | 3.184218 | 249.003 |
| 2007 | 1.758366 | 142.4612 | 1748.171 | 168.7323 | 3.073924 | 240.3781 |
| 2008 | 1.745464 | 141.4159 | 2159.31 | 208.4152 | 3.768998 | 294.7323 |
| 2009 | 1.930335 | 156.394 | 2705.988 | 261.1803 | 5.223464 | 408.4702 |
| 2010 | 1.6316 | 132.1907 | 3013.871 | 290.8969 | 4.917432 | 384.5388 |
| 2011 | 2.40742 | 195.047 | 2838.152 | 273.9366 | 6.832623 | 534.305 |
| 2012 | 2.079214 | 168.456 | 2581.072 | 249.1234 | 5.3666 | 419.6633 |
| 2013 | 1.777698 | 144.0275 | 2461.226 | 237.5559 | 4.375316 | 342.1458 |
| 2014 | 1.996982 | 161.7937 | 1681.728 | 162.3193 | 3.35838 | 262.6223 |
| 2015 | 2.024942 | 164.059 | 1517.504 | 146.4685 | 3.072858 | 240.2947 |
| 2016 | 2.047612 | 165.8957 | 1430.577 | 138.0783 | 2.929266 | 229.066 |
| 2017 | 2.070136 | 167.7205 | 1381.164 | 133.3091 | 2.859198 | 223.5867 |
| Average | 1.740499 | | 1645.94 | | 2.952484 | |

Source: Authors' computation, 2018

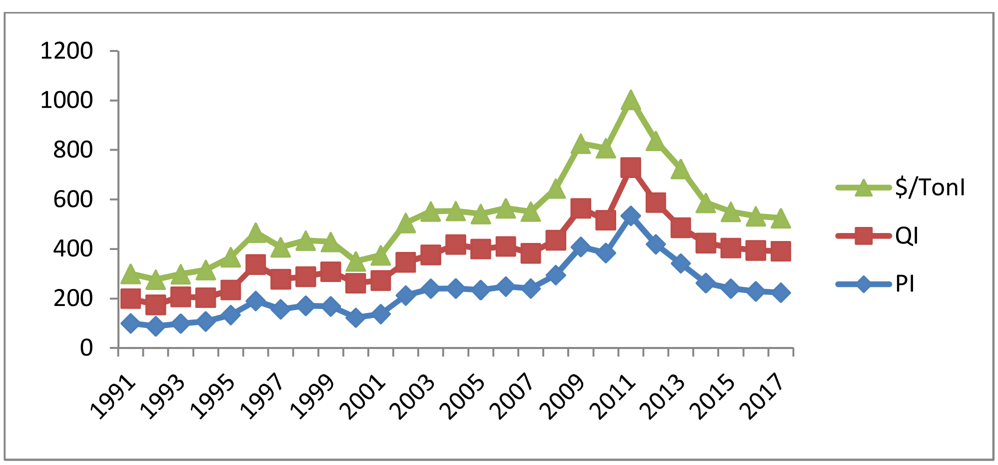


**Figure 1: African export trend of cocoa beans**

Note: Ton= ton; Q = Export quantity; P= Value of export; I = Index

**Table 1b: Growth rate of cocoa export from 1991-2017**

| Variable | Export (ton) | Export ($) |
|---|---|---|
| Intercept | 1.26924e+6 | 1.171963393 |
| Slope | 33661.2*** | 127180019.5*** |
| Average | 1740499 | 2952484 |
| Annual change (%) | 1.9 | 4.31% |
| $R^2$ | 0.635 | 0.513 |
| F-statistic | 43.5*** | 26.4*** |

Source: Authors' computation, 2018

### 3.2. Degree of stability of African cocoa export

The results revealed a low instability in the quantity and value of cocoa exports as evidenced by their respective instability indexes, which were less than 20% (Table 2). This indicates that African cocoa export has a competitive advantage in the global cocoa market.

**Table 2: Stability index of African cocoa export**

| Variable | Index (%) |
|---|---|
| Export (ton) | 12.25 |
| Export ($) | 18.16 |

Source: Authors' computation, 2018

### 3.3. Export concentration index

The estimated Gini coefficient index of 0.584 indicated that the level of geographical trade concentration of African cocoa export to the global world is moderate (Table 3). This was justified by the Lorenz curve, which is moderately farther from the line of equity (Figure 2). The highest importing continent of African cocoa is European continent (1.08 million MT) while Australian continent is the least importer (101 tons).

**Table 3: Export concentration**

| Item | Index |
|---|---|
| Sample Gini coefficient | 0.584 |
| Estimate of population value | 0.730 |

Source: Authors' computation, 2018

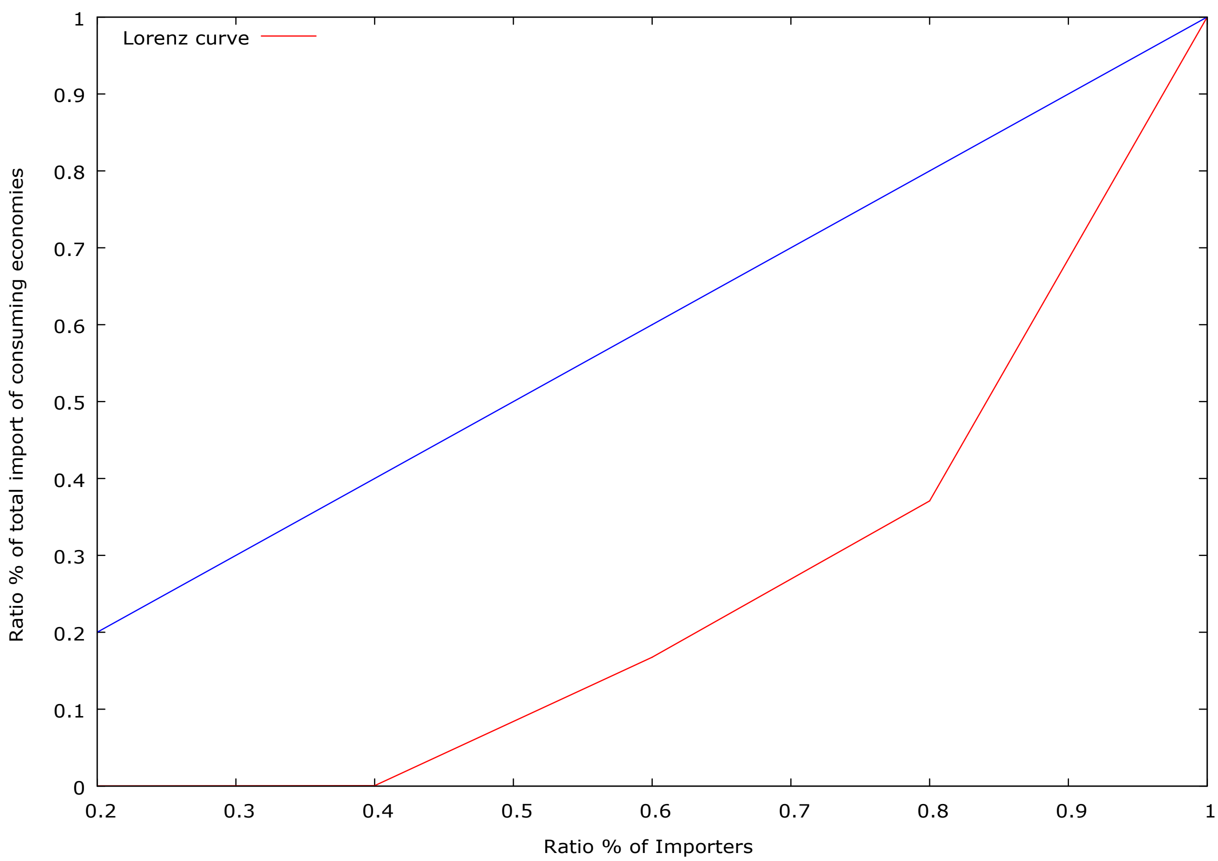


**Figure 2: Lorenz curve of current export to the consuming economies**

### 3.4. Redirecting export of African cocoa

The Linear programming algorithm was implemented for redirecting exportation of cocoa from Africa. It is assumed that if the cocoa import share of high-income continents from Africa is less than 10%, Africa can increase its export volume to those continents by 10% of the continent's import capacity. Furthermore, the export can be increased by 20% of the continent's import capacity if its import share from Africa is more than 10% and less than 20% of its total cocoa import. Contrarily, there will be no change in a continent's import if its share of Africa cocoa export is equal or more than 40%.

The average annual cocoa exports across the selected continents for the period of 1991 to 2017 was 1.55 million MT at an approximate value of $ 2.87 billion, and the LP results revealed that Africa has the capacity of exporting 2.66 million MT (41.59%) at an approximate value of $4.85 billion, which export gain is approximately $1.98 million (40.90%)(Table 4). Furthermore, the optimal solution showed that the export value of African cocoa across the selected continent would increase. The import value of European continent is the highest while Australian continent import is the least. However, the feasible solution suggested a decrease of the export quantity to Oceania continent.

The suggested geographic re-distribution of African cocoa export leads to a decrease in the Gini coefficient to 0.174 from 0.584, thus, indicating an increase in the level of geographical trade concentration.

### 3.5. Determinants of export performance

#### 3.5.1. *The unit root test*

The results of the ADF and KPSS (Kwiatkwoski, Phillips, Schmidt and Shin) unit root tests indicated the presence of unit root at level for all the variable series as they were found to be non-significant at 5% probability. Thereafter, after first differencing the unit roots was absent in the residuals as indicated by the significance of the variable series at 5% probability level (Table 5). However, the weakness of the widely used traditional unit roots made the researchers to verify the robustness and efficiency of the estimated tau-statistics using the neo-classical unit root test (ERS). The ERS (Elliott, Rothenberg and Stock) unit root test indicated that the variable series were integrated of order one [I (1)], thus, upholding the robustness and efficiency of the estimated tau-statistics obtained from the conventional unit root tests. Therefore, since the variable series were integrated of order one, the application of co-integration test become justifiable.

#### 3.5.2. *Co-integration test*

The Engel-Granger two-step procedure was applied to test the existence of long-run association among the variables (Table 6). However, for co-integration test, two criteria had to be met: the variables should be integrated of order one [I(1)], then the residual from the co-integrating relationship should be integrated of order zero [I(0)]. The results of the ADF unit root test applied to the residual of the linear combination of these variables level indicated that the residual variable is integrated of an order one less than the original order of the variable as evidenced by the tau-statistics, which is lesser than the Engel-Granger critical value at 5% degree of freedom. In other words, it means the residual of the variable has no unit root at level, thus, integrated of order zero [I (0)]. Therefore, since the residual is found to be integrated of order zero, it becomes justifiable to apply the linear price symmetric model (Error correction model).

**Table 4: Redirecting African cocoa export**

| Continent | Total import (ton) | Current situation | | | | Optimal solution | | | | Redistribution | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Quantity | | Value | | Quantity | | Value | | | |
| | | ton | % | $ | % | ton | % | $ | % | Qty | Value |
| America | 517020 | 337859.30 | 21.74 | 586933.50 | 20.48 | 533817.60 | 20.06 | 898008.30 | 18.52 | -195958.30 | -311075 |
| Asia | 42453.72 | 135143.70 | 8.69 | 293466.80 | 10.24 | 397322.50 | 14.93 | 921485.70 | 19 | -262178.80 | -628019 |
| Europe | 1599574 | 1081150 | 69.56 | 1966227 | 68.61 | 1729839 | 65 | 2910016 | 60.01 | -648689 | -943789 |
| Oceania | 724.87 | 118 | 0.006 | 17880 | 0.62 | 12.98 | 0.00 | 109783.20 | 2.26 | 105.02 | -91903.2 |
| Austria & NZ | 660.87 | 101 | 0.004 | 1527 | 0.05 | 128.27 | 0.01 | 9986.58 | 0.21 | -27.27 | -8459.58 |
| Total | 2160433.46 | 1554372 | 100 | 2866034.30 | 100 | 2661120 | 100 | 4849280 | 100 | -1106748 | -1983245 |
| Change | | | | | | | 1106748 | | 1983245 | | |
| % | | | | | | | 41.59 | | 40.90 | | |

**Table 5: Stationarity test**

| Items | Stage | ADF | KPSS | ADF-GLS |
|---|---|---|---|---|
| EXPQ | Level | -2.33(0.172)$^{NS}$ | 0.927$^{NS}$ | -1.76(0.074)$^{NS}$ |
| | $1^{st}\Delta$ | -5.51(1.6e-6)$^{S}$ | 0.087$^{S}$ | -6.01(4.3e-9)$^{S}$ |
| TOP | Level | -2.16(0.227)$^{NS}$ | 0.160$^{NS}$ | -2.391$^{NS}$ |
| | $1^{st}\Delta$ | -4.69(0.001)$^{S}$ | 0.042$^{S}$ | -5.136$^{S}$ |
| CPQ | Level | -1.41(0.578)$^{NS}$ | 1.144$^{NS}$ | -2.338$^{NS}$ |
| | $1^{st}\Delta$ | -6.65(1.9e-5)$^{S}$ | 0.130$^{S}$ | -6.961$^{S}$ |
| EXR | Level | -2.53(0.122)$^{NS}$ | 0.244$^{NS}$ | -1.836$^{NS}$ |
| | $1^{st}\Delta$ | -4.39(0.003)$^{S}$ | 0.085$^{S}$ | -5.103$^{S}$ |
| INF | Level | -2.64(0.100)$^{NS}$ | 0.249$^{NS}$ | -1.408$^{NS}$ |
| | $1^{st}\Delta$ | -3.04(0.047)$^{S}$ | 0.067$^{S}$ | -3.699$^{S}$ |
| AMGDP | Level | -0.84(0.787)$^{NS}$ | 1.225$^{NS}$ | -2.438$^{NS}$ |
| | $1^{st}\Delta$ | -4.06(0.006)$^{S}$ | 0.083$^{S}$ | -4.246$^{S}$ |
| ASGDP | Level | -1.40(0.861)$^{NS}$ | 1.133$^{NS}$ | -1.058$^{NS}$ |
| | $1^{st}\Delta$ | -3.32(0.027)$^{S}$ | 0.204$^{S}$ | -3.517$^{S}$ |
| EGDP | Level | -0.24(0.920)$^{NS}$ | 1.126$^{NS}$ | -1.719$^{NS}$ |
| | $1^{st}\Delta$ | -3.80(0.003)$^{S}$ | 0.114$^{S}$ | -3.582$^{S}$ |
| WP | Level | -2.17(0.218)$^{NS}$ | 0.847$^{NS}$ | -2.555$^{NS}$ |
| | $1^{st}\Delta$ | -5.70(6.1e-7)$^{S}$ | 0.043$^{S}$ | -3.453$^{S}$ |
| AC | Level | -0.09(0.939)$^{NS}$ | 0.848$^{NS}$ | -1.990$^{NS}$ |
| | $1^{st}\Delta$ | -5.24(4.1e-4)$^{S}$ | 0.329$^{S}$ | -6.008$^{S}$ |
| DFI (Africa) | Level | -1.22(0.669)$^{NS}$ | 1.214$^{NS}$ | -1.974$^{NS}$ |
| | $1^{st}\Delta$ | -7.08(7.3e-6)$^{S}$ | 0.132$^{S}$ | -3.593$^{S}$ |

Note: Δ, NS and S indicates first difference, non-stationary and stationary at the level or at first difference at 5 percent significance. The critical values for the KPSS and ADF-GLS test at 5% probability are 0.462 and 3.19 respectively.

**Table 6: Co-integration test**

| Residual (U) | τ-statistic | Engel-Granger critical value | | Decision |
|---|---|---|---|---|
| | | 5% | 10% | |
| Cocoa | -5.430* | -3.34 | -3.04 | Stationary at level I(0) |

Note: * indicate that unit root at the level was rejected at 5% significant level

### 3.5.3. *The long-run dynamic cocoa export response function*

The macro indicators which have impact on the decision of the current export quantity of African cocoa were the lagged TOP, lagged EXR, lagged WP and lagged EXPQ as evidenced by their respective estimated coefficients which were different from zero at less than 1% probability level (Table 7a). The detailed decomposition showed that lagged TOP had positive impact on the current export quantity of African cocoa beans while the lagged EXR, lagged WP and the lagged EXPQ had negative impact on the current export quantity of African cocoa beans. In other words, it means that the former increase the current quantity of cocoa beans exported to the global market from African while the latter decrease the current export quantity of African cocoa beans to the global cocoa market.

The positive relationship of the lagged TOP with the current quantum of cocoa exported from African (EXPQ) indicates the integration of Africa in the trade of cocoa beans into the global economy. Even though agricultural commodities from developing countries faced trade barriers in respect of tariff escalation and quotas in the importing advanced economies, there is evidence of market liberalization in cocoa beans as there is a zero tariff regime and less stringent trade regulations for the product. Consequently, African has taken the advantage in the production and exportation of the cocoa beans to the Western consumers, notably Europe and the USA.

The inverse relation of the lagged price factors showed how the fluctuating exchange rate (EXR) and the world price (WP) of cocoa beans, which did not yield remunerative returns, affected the current export quantity of cocoa beans exported from African. Furthermore, the lagged price disincentive on the lagged EXPQ was carried forward to the subsequent period as it reduced the current EXPQ of cocoa beans from Africa.

The elasticity implication of a percent increase in the in the lagged TOP will lead to 0.80% increase in the current quantity of cocoa to be exported from Africa. The elasticity implication of a percent increase in the lagged EXR lagged WP and lagged EXPQ will results in the decrease of the current EXPQ of African cocoa beans by 0.24%, 0.56% and 1.16% respectively. The negative inelastic relationships for the first two former showed how fear of glut i.e. cob-web effect which create a downswing in the price of cocoa will force Africa exporters to reduce their current export quantity of cocoa to the international markets.

The coefficient of multiple determination index showed that 86.8% of the current cocoa EXPQ was determined by the macro-economic indicators captured by the model. In addition, the significance of the F-statistics at less than 10% degree of freedom implied that the estimated coefficient parameters in the long-run dynamic model are different from zero at 10% probability level, thus, they have significant influence on the current EXPQ of cocoa.

#### 3.5.4. *The short-run dynamic cocoa export response function*

The short-run dynamics measured by the ECM showed negative and statistically significant attractor coefficient (ECT) (Table 7a). This implied that a price shock that induces current EXPQ deviation from the equilibrium level would induce African exporters to respond to the shock in a way that the current EXPQ would converge toward the equilibrium value. Furthermore, there is delay in the short-run EXPQ transmission as the coefficients of the lagged macroeconomic indicators were different from zero at 10% probability level. The significance of the attractor coefficient value of 1.38 ($p < 0.001$) implies that the current EXPQ corrects its previous deviation due to short-run shocks or distortion from the equilibrium at the speed of 138.0%.

In other words, it means that about 138% of the disequilibrium experienced in cocoa exports in the previous year is restored back to the long-run equilibrium position within a year after the disturbance or shock. The time required for the current EXPQ to re-establish its equilibrium from disequilibrium will be approximately 16.7 months. The adjustment rate will be very low, an indication of weak efficiency in the degree of integration of the African EXPQ with the global world market of cocoa.

The macroeconomic indicators with significant effect on the current EXPQ were the lagged TOP, lagged CPQ, lagged EXR, lagged EGDP, lagged WP, lagged AC and lagged EXPQ as indicated by their respective estimated parameters, which were different from zero at 10% risk level. The detailed decomposition results showed lagged TOP, lagged CPQ and lagged EGDP to have positive effect on the current EXPQ while the lagged EXR, lagged WP, lagged AC and lagged EXPQ had negative effect on the current cocoa EXPQ.

The elasticity implication of 1% increase in TOP will lead to an increase in the current cocoa EXPQ by 0.69%, thus, indicating the share of Africa integration into the cocoa global trade in the short-run. The elasticity implication of a percent increase in the quantity of cocoa bean produced (CPQ) will boost or spur the export performance of cocoa bean by 0.58%, *ceteris paribus*. This indicates the presence of inventory accumulation accentuated by comparative advantage of the continent in the production of this commodity. Cocoa is not only a notable cash crop and principal export commodity for West African producing economies but also it is a critical import product for consuming countries, which typically do not have favorable climatic conditions for the cultivation of the crop. Consequently, major consuming and processing economies have to import the product as posited by some trade theories.

The price elasticity implication of a percent increase in the EXR and WP will decrease the current cocoa EXPQ by 0.19% and 0.47% respectively. The negative connection (infinite elasticity) of the price factor unfolds two scenarios: disincentive effect of oscillating downswing price fluctuation on the export performance and the fear of lagged oscillating upswing price volatility, which will dampen the future price of cocoa bean due to glut of the commodity in the global market. The previous price disincentive that affects the previous export quantity ($EXPQ_{t-1}$) reared its ugly trend on the decisions for current EXPQ. The elasticity implication of 1% increase in the lagged EXPQ will force the exporters to decrease their current cocoa EXPQ to the global cocoa market by 0.90%.

The implication of a percent increase in the income elasticity of Europeans will increase the current EXPQ by 0.45. The inelasticity of the income empirically indicated that cocoa bean commodity is a necessity in Europe. In addition, it revealed the critical importance of cocoa as an import product for the consuming European countries which typically lack the favorable climatic conditions for cultivation of the crop. The moderate-income elasticity is evidence of the gradual pace or moderate speed of adaptation of the export to the local tastes in the European importing countries.

The negative connection of credit (AC) with the current EXPQ revealed the effect of high interest rate charged on non-equity capital extended to the cocoa exporters. Consequently, the high cost of capital has posed a constraint to the exportation of cocoa bean in Africa. Therefore, the elasticity implication of 1% increase in the AC will result in the decrease of current EXPQ by 14%.

The results of the coefficient of multiple determination showed that 91.2% variation in the response variable was influenced by the stimulus variables captured by the model. Furthermore, the significance of the F-statistic at 1% probability level indicated that the estimated coefficients are not *cruzeiros* (different from zero at 10% risk level), indicating that the estimated parameters have significant influence on the cocoa export response.

### 3.5.5. *Diagnostic test*

The results of the diagnostic tests showed that the residual of the short-run dynamic model is devoid of serial correlation and auto-covariance as indicated by the Autocorrelation Langrage multiplier test and the Arch effect LM test, which were not different from zero at 10% degree of freedom. In addition, the residual is found to be normally distributed as shown by the $Chi^2$ test statistic which is not different from zero at 10% probability level (Table 7a). Structural break or change in the parameters was not present in the equation as indicated by the CUSUM Harvey-Collier test, which is not different from zero at 10% risk level. The multicollinearity test showed no presence of covariance between the predictor variables as indicated by their respective variance inflation factors (VIF) which was less than 10.00 (Table 7b).

**Table 7a: Long-run and short-run predictions for current cocoa EXPQ**

| Long-run dynamic model (LNEXPQ) | | | Short-run dynamic model (ΔLNEXPQ) | | |
|---|---|---|---|---|---|
| Variable | Coefficient | t-ratio | Variable | Coefficient | t-ratio |
| Constant | 2.794(8.081) | 0.346$^{NS}$ | Constant | -0.053 (0.033) | 1.615$^{NS}$ |
| $LNTOP_{t-1}$ | 0.804(0.115) | 6.967*** | $\Delta LNTOP_{t-1}$ | 0.686 (0.163 | 4.219*** |
| $LNCPQ_{t-1}$ | 0.499 (0.383) | 1.305$^{NS}$ | $\Delta LNCPQ_{t-1}$ | 0.579(0.157) | 3.691*** |
| $LNEXR_{t-1}$ | -0.244(0.059) | 4.158*** | $\Delta LNEXR_{t-1}$ | -0.193(0.085) | 2.275* |
| $LNINF_{t-1}$ | 0.009(0.032) | 0.274$^{NS}$ | $\Delta LNINF_{t-1}$ | -0.007(0.019) | 0.351$^{NS}$ |
| $LNAMGDP_{t-1}$ | 1.515(0.982) | 1.544$^{NS}$ | $\Delta LNAMGDP_{t-1}$ | 1.691(0.974) | 1.736$^{NS}$ |
| $LNASGDP_{t-1}$ | -0.003(0.164) | 0.020$^{NS}$ | $\Delta LNASGDP_{t-1}$ | 0.185(0.180) | 1.029$^{NS}$ |
| $LNEGDP_{t-1}$ | 0.128(0.129) | 0.988$^{NS}$ | $\Delta LNEGDP_{t-1}$ | 0.453(0.161) | 2.822** |
| $LNWP_{t-1}$ | -0.560(0.103) | 5.446*** | $\Delta LNWP_{t-1}$ | -0.470(0.095) | 4.944*** |
| $LNAC_{t-1}$ | -0.074(0.078) | 0.959$^{NS}$ | $\Delta LNAC_{t-1}$ | -0.142(0.046) | 3.107** |
| $LNDFI_{t-1}$ | -0.123(0.175) | 0.705$^{NS}$ | $\Delta LNDFI_{t-1}$ | -0.031(0.056) | 0.556$^{NS}$ |
| $LNEXPQ_{t-1}$ | -1.155(0.170) | 6.814*** | $\Delta LNEXPQ_{t-1}$ | -0.896(0.185) | 4.858*** |
| $R^2$ | 0.868 | | $ECT_{t-1}$ | -1.380(0.131) | 10.57*** |
| $R^2$Adjusted | 0.723 | | $R^2$ | 0.912 | |
| Durbin-Watson | 1.974 | | $R^2$adjusted | 0.779 | |
| F-statistic | 239*** | | Durbin-Watson | 1.07 | |
| | | | F-statistic | 225** | |
| | | | Autocorrelation | 0.32(0.58)$^{NS}$ | |
| | | | Arch effect | 0.02(0.89)$^{NS}$ | |
| | | | Heteroscedasticity test | 7.51(0.82)$^{NS}$ | |
| | | | Normality test | 2.90(0.24)$^{NS}$ | |
| | | | CUSUM test | 0.24(0.81)$^{NS}$ | |

Source: Authors' computation, 2018; Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1; NS = Non-significant

**Table 8: Granger causality test results**

| Null hypothesis | F-stat | P< 0.10 | Granger cause | Direction |
|---|---|---|---|---|
| EXPQ ↔ TOP | 4.345 | 0.067 | No | None |
| | 0.134 | 0.723 | No | |
| EXPQ ↔ CPQ | 0.062 | 0.810 | No | None |
| | 0.457 | 0.516 | No | |
| EXPQ ↔ EXR | 3.345 | 0.101 | No | None |
| | 0.086 | 0.775 | No | |
| EXPQ ↔ INF | 1.159 | 0.310 | No | Unidirectional |
| | 8.852** | 0.017 | Yes | |
| EXPQ ↔ AMGDP | 2.484 | 0.149 | No | None |
| | 0.105 | 0.753 | No | |
| EXPQ ↔ ASGDP | 0.831 | 0.386 | No | Unidirectional |
| | 18.21** | 0.002 | Yes | |
| EXPQ ↔ EGDP | 0.397 | 0.544 | No | None |
| | 0.192 | 0.672 | No | |
| EXPQ ↔ WP | 3.308 | 0.102 | No | Unidirectional |
| | 6.896** | 0.028 | Yes | |
| EXPQ ↔ AC | 1.229 | 0.296 | No | Unidirectional |
| | 6.182** | 0.035 | Yes | |
| EXPQ ↔ DFI | 0.917 | 0.363 | No | None |
| | 2.541 | 0.145 | No | |

Note: **denotes rejection of the $H_0$ at 5% level of significance; NS: Non-significant; $\rightarrow \leftarrow$ *means forward and backward directions respectively*

**Table 7b: Multicolinearity test**

| Variable | VIF |
|---|---|
| $\Delta LNTOP_{t-1}$ | 1.130 |
| $\Delta LNCPQ_{t-1}$ | 3.883 |
| $\Delta LNEXR_{t-1}$ | 2.269 |
| $\Delta LNINF_{t-1}$ | 1.637 |
| $\Delta LNAMGDP_{t-1}$ | 4.956 |
| $\Delta LNASGDP_{t-1}$ | 1.649 |
| $\Delta LNEGDP_{t-1}$ | 2.721 |
| $\Delta LNWP_{t-1}$ | 4.475 |
| $\Delta LNAC_{t-1}$ | 1.607 |
| $\Delta LNDFI_{t-1}$ | 2.507 |
| $\Delta LNEXPQ_{t-1}$ | 6.126 |
| $ECT_{t-1}$ | 1.565 |

Note: VIF > 10.0 may indicate collinearity problem

### 3.5.6. *Causality relationship*

The granger causality results showed that the macro-economic indicators *viz*. CPI, ASGDP, WP, AC had useful information to predict the future formation of EXPQ as shown by their respective F-statistics which were different from zero at 5% degree of freedom. In the case of the EXPQ, it has no useful information to predict the future formation of the aforementioned macro-economic indicators as indicated by its F-statistics which were not different from zero at 5% degree of freedom (Table 8). However, a slight adjustment forward of the degree of freedom (> 5 but ≤ 10) showed that the EXPQ granger cause formation of TOP but the latter did not granger cause the formation of the former. Therefore, it can be inferred that the export performance of cocoa in the long-run has been determined by the purchasing and earning power of money. The causal effect of the EXPQ on the TOP justified the earlier findings on the integration of the Africa into the global cocoa trade.

## 4. Conclusions and Recommendation

Evidences show that the geographical trade concentration of African cocoa in the global market is very low and by adopting the optimal solution preferred by the LP the geographical trade concentration will increase. The African cocoa export has a competitive advantage in the global cocoa trade market as its export quantity is found to be very stable. Furthermore, the current export quantity of cocoa had log-run association with the macro-economic indicators and any price shock that induced current EXPQ deviation from the equilibrium level would induce African exporters to respond to the shock in a way that the current EXPQ would converge toward the equilibrium. The major macro-economic indicators affecting the export performance of African cocoa in both the long and short-runs is the price factor. Therefore, the continental bloc (African Union) should enhance the trade mechanism of cocoa by strengthening the price policy so that the dampening price effect affecting remunerative price in the international market should be nip in the bud. There is a need to improve the quality of African cocoa in order to increase the competitive prowl of the product in the global cocoa market. In addition, the regional body and the major exporting economies financial export institutions in Africa should reduce the cost of non-capital equity advanced to the exporters as high interest rate is affecting export performance of the product. The continent should increase its export to the importing economies as it has the capacity to increase its current export capacity by 41.73% with approximate export value gain of 40.82%.

### Conflict of Interest

The authors declare that there is no conflict of interest.

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# Optimum Nitrogen and Phosphors Fertilizer Rates for Upland Rice Production in North Western Ethiopia

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Received: October 14, 2019 Accepted: February 17, 2020

**Abstract:** *The national average yield of rice is about 2.8t ha$^{-1}$ which is lower compared to the world average productivity of 4.6 tones ha$^{-1}$ mainly constrained by soil nutrient deficiencies. An experiment on nitrogen and phosphorous fertilizer rates was conducted on upland rice on Nerica-4 variety in Fogera and Libokemkem districts in three consecutive main cropping seasons of the years 2015, 2016 and 2017 to determine the appropriate rates for production. The treatments were comprised of factorial combinations of four nitrogen rates (0, 46, 92,138 N kg ha$^{-1}$) and three phosphorous rates (0, 46, 92 $P_2O_5$ kg ha$^{-1}$), and laid out in randomized complete block design (RBD) with three replications. Data were collected on plant height, panicle length, and number of total tillersm$^{-2}$, number of fertile panicles m$^{-2}$, thousand seeds weight, grain yield, straw yield and harvest index. All collected data were subjected to analysis of variance. Economic analysis was also carried out by following CIMMYT (1988) procedures. The results of the experiment indicated that the main effect of nitrogen application significantly affected plant height, panicle length, total tillers, number of fertile panicles, grain yield, and straw yield, while that of phosphorous significantly affected total tillers, number of fertile panicles and grain yield. The interaction of nitrogen and phosphorous was significantly affecting total tillers, number of fertile panicles, grain yield and straw yield. The highest grain yield (5.5 t ha$^{-1}$) was obtained from the interaction of 138 kg ha$^{-1}$N with 46 kg ha$^{-1}$ $P_2O_5$. The economic analysis has further revealed that the combined application of 138 kg ha$^{-1}$N and 46 kg ha$^{-1}$ $P_2O_5$ which gave the highest net return of Birr 68,307.5 ha$^{-1}$ was the most profitable treatment to upland rice production. Thus it is concluded that application of nitrogen and phosphorous fertilizers at the rates of 138-46 N-$P_2O_5$ kg ha$^{-1}$ is the best to be recommended for rainfed upland rice production in the study area and other similar agro-ecologies.*

**Keywords:** Nitrogen, Phosphorous, Productivity, Profitability, Upland rice.



## 1. Introduction

Rice *(Oryza sativa* L.) is an annual cereal crop and it is one of the most important food crops for the world's population, especially in South Asia, Middle East, Latin America and West India (Zhao *et al.*, 2011). It is the principal food for one third of the world's population. More than 90% of rice is produced and consumed in Asia (Subedi *et al.*, 2019). It provides some 700 calories per person, mostly residing in developing countries. In Ethiopia, rice production was started three decades ago in the early 1970's and the country has reasonable potential to grow various rice types mainly in rain fed lowland, upland and irrigated ecosystems (Mulugeta and Heluf, 2005). Although rice is a recent introduction to the country, its importance is well recognized as the production area coverage of about 10,000 ha in 2006 has increased to over 63,000 ha in 2018 (CSA 2019). The area coverage in domestic rice production has increased considerably linked with expansion of production in the wetland and upland areas with the introduction of suitable rice varieties for the agro-ecologies. In line with the area expansion, the production levels have been increasing consistently over years. CSA (Central Statistical Authority) data indicates that rice production has increased from 71,316.07 tons in 2008 to 171,854.09 tons in 2018 (CSA, 2019). The number of farmers engaged in rice production has also grown year after year. Rice production has brought a significant change in the livelihood of farmers and created job opportunities for a number of citizens in different areas of the country. Currently, Amhara, Southern Nations Nationalities and Peoples Region (SNNPR), Oromiya, Somali, Gambella, Benishangul-Gumuz, and Tigray regions are the rice producing areas in Ethiopia (MoARD, 2010). The Amhara region takes the lion's share of producing the crop and accounted for 74-81% of the area coverage and 78-85% of the production in the years of 2016-2018 (CSA, 2016; CSA, 2017; CSA, 2018). According to the report of MoARD (2010), the potential rice production area in Ethiopia is estimated to be about 39,354,190 hectares, of which 5,590,895 ha is highly suitable, 24,910,629 ha are suitable and 8,852,666 are moderately suitable. Most of Ethiopia's rice production potential area lies in the western part of the country.

Upland rice could suitably grow in many parts of Ethiopia. Predominant potential areas include west central highlands of Amhara Region (Fogera, Gonder Zuria, Dembia, Takusa and Achefer), North West lowland areas of Amhara and Benshangul Regions (Jawi, Pawi, Metema and Dangur), Gambella Regional State (Abobo and Etang Woredas), South and South West Low lands of Southern Nations, Nationalities and Peoples Region (SNNPR) (Beralle, Weyito, Omorate, Gura Ferda and Menit), Somali Region (Gode), Afar and South western highlands of Oromia Region (Illubabora, East and West Wellega and Jima Zones) (Dawit, 2015). The national average yield of rice is about 2.8t $ha^{-1}$ (CSA, 2018), which is lower compared to the world average productivity of 4.6 t $ha^{-1}$ (FAOSTAT, 2018). Weeds, pests, soil nutrient deficiencies and terminal moisture stress are the major causes of low rice productivity in Ethiopia (MoARD, 2010; Gebey *et al*., 2012). Poor soil fertility is among the major factors limiting rice production in Ethiopia. Nitrogen, phosphorus, and potassium are applied as fertilizers in large quantities to rice fields and a deficiency of either of the nutrient leads to yield losses (Aamer *et al.*, 2000; Sharada *et al*., 2018; Masni and Wasli, 2019; Subedi *et al.*, 2019). Nitrogen and phosphorus are often cited as the most limiting nutrients in agricultural soils of Ethiopia (Molla and Sofonyas, 2018). Appropriate fertilizer application is an important management practice to improve soil fertility and production of rice (Maneesh *et al*. 2018). Unlike the rain fed lowland ecosystem, fertilizer recommendations were not developed for the rain fed upland ecosystem of the study area. Therefore, a fertilizer experiment was conducted on the upland rice production of Fogera and Libokemkem Woredas in order to recommend appropriate levels of nitrogen and phosphorous rates.

## 2. Materials and Methods

An experiment on nitrogen and phosphorous plant nutrients was conducted on upland rice in Fogera and Libokemkem districts in three consecutive cropping seasons of the years of 2015, 2016 and 2017on a total of twelve on farm sites. The study at Fogera area is situated at 11 °54.4'46.3"N to 11 °57'03.0"N latitude and 37 °41'23.9"E to 37 °42'32.2" E longitude at elevation range of 1787-1812 meter above sea level. The geographical location of the experimental area at Libokemkem is located at 12º 1′ 30″ N to 12º 12′ 00″ N latitude and 37º 31′ 30″ E to 37º 52′ 30″ E longitudes with the altitude range of 1804 to 1910 meter above sea level. The study site receives mean annual rainfall of1219 mm with annual average minimum and maximum temperature of 12.75°C and 27.37°C, respectively. The long-term rainfall data (1986-2017) indicated that much of the rainfall occurs in July and August (Figure 1).

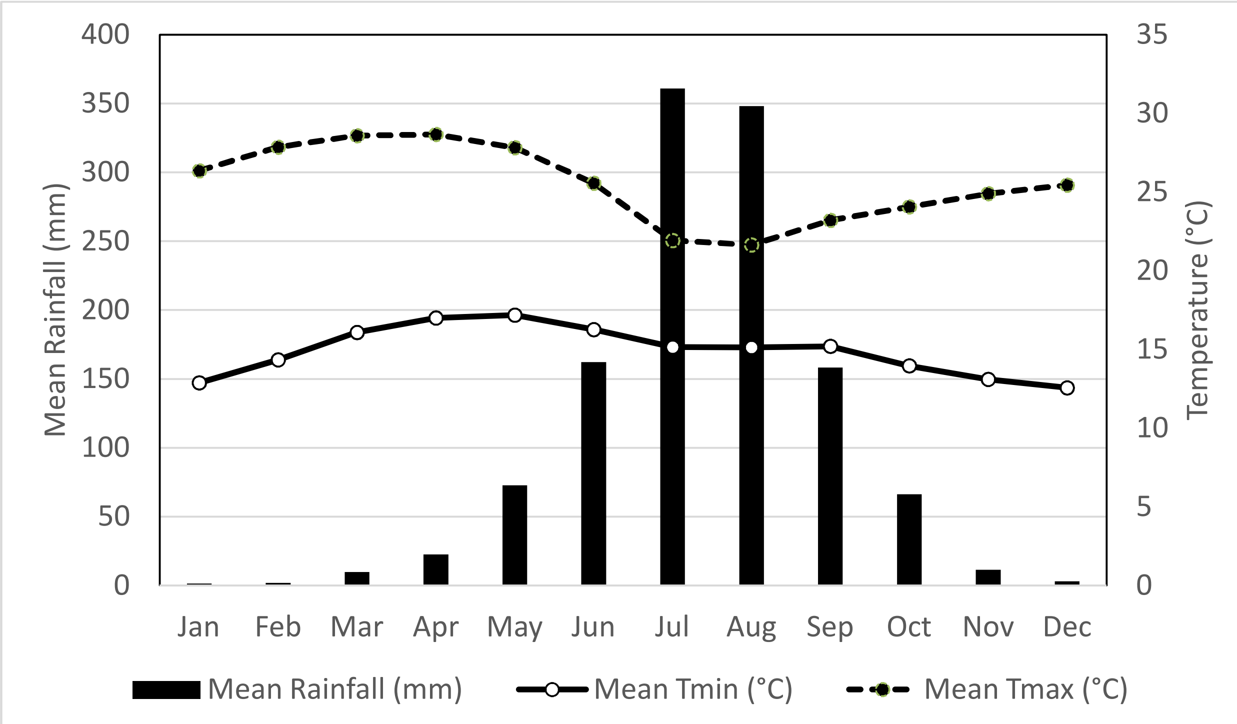


**Figure 1: Mean monthly total rainfall, and monthly average minimum and maximum temperatures of the study area for the period 1981-2017**

Composite soil samples for each experimental site was collected before planting for major physical and chemical analyses using the standard procedures. The soil samples were collected, air-dried, ground, sieved to pass a 2-mm mesh and composited into one. Soil analysis was carried out from the composite sample in duplicates where soil samples were analyzed for soil texture using Bouyoucos hydrometer method (Bouyoucos, 1962). Total nitrogen following the Kjeldahl procedure method (Sahlemedhin and Taye, 2000) and Soil was also analyzed for pH (1:2.5 soil: water) by using pH meter (Sahlemedhin and Taye, 2000). While organic carbon was determined using wet digestion method (Walkely and Black, 1934) available phosphorus was using Bray II method (Bray, 1954).

The textural class of the experimental soil was found to be heavy clay with the pH of 5.87-6.08, which is slightly acidic and it is a preferred range for most crops (Table 1). Total nitrogen content was 0.09-0.11%, which is within the range of low levels (0.02-0.5%) for tropical soils. The organic matter content of the soil was 2.13-2.39%, which is within a range of medium (2-4%) for Ethiopian soils as per criteria developed by Murphy (1968). The available P content of the experimental soil was 11.4-25.13ppm that lies in a range of deficiency (< 20-40mg/kg) for most crops (Landon, 1991).

**Table 1: Relevant soil physicochemical properties of the experimental rice field before planting**

| Soil properties | Units | Minimum value | Maximum value |
|---|---|---|---|
| Textural class | | Heavy clay | Heavy clay |
| Chemical properties | | | |
| pH ($H_2O$) 1:2.5 g soil | - | 5.87 | 6.08 |
| Total nitrogen (TN) | % | 0.09 | 0.11 |
| Organic carbon (OC) | % | 1.24 | 1.33 |
| Organic matter (OM) | % | 2.13 | 2.29 |
| Available Phosphorus | Ppm | 11.4 | 25.13 |

The treatments were comprised of factorial combinations of four nitrogen (0, 46, 92, 138 N kg $ha^{-1}$) and three phosphorous levels (0, 46, 92 $P_2O_5$ kg

$ha^{-1}$) in Randomized Complete Block Design and replicated three times. The gross size of the experimental plots was 3m x 4m consisting of 15 rows planted at a spacing of 20 cm apart with the seeding rate of 100 kg $ha^{-1}$. The net plot area was made by excluding the left and right outer rows and a plot length of 0.5 m from the top and bottom sides of the plot. The final net plot size was thus 2.6m x 3m. Data on plant height, panicle length, number of total tillers$m^{-1}$ row length, number of fertile panicles $m^{-1}$ row length, thousand seeds weight, grain yield, straw yield and harvest index were collected timely from the net plot areas following their respective standard measuring methods and procedures. The rice grain yield and thousand seeds weight were adjusted at 14% standard moisture content. All collected data were subjected to analysis of variance (ANOVA) using SAS software version 9.0 (SAS-Institute, 2003). Since the test of homogeneity of variances for each parameter was non-significant, combined analysis of variance was done over the years to determine the effects of nitrogen and phosphorous fertilizers on rice production. Wherever the ANOVA results showed significant difference between treatments for a variable, mean separation between treatments was executed by using Least Significant Difference (LSD) method at probability levels of 0.01 or 0.05 depending on the ANOVA results. Moreover, agronomic efficiency (AE) was calculated to assess the use efficiencies of the applied N rates as follows:

$$AE = \frac{Gf - Gu}{Na}$$

Source: Liu *et al.* (2019)

Where:

AE = agronomic efficiency

Gf = grain yield of the fertilized plot (kg)

Gu = grain yield of the unfertilized plot (kg)

Na = rate of applied N fertilizer (kg)

Economic analysis was carried out by following CIMMYT (1988) procedures by taking all variable costs. The prevailing cost of inputs and out puts in year 2019 were considered for the analysis. The costs of Urea and NPS fertilizers for the stated period at the study area were Birr 13.1 and 14.3 per kg, respectively, while the prices of rice grain and straw were Birr 13.5 and 1.2 per kg, respectively.

## 3. Results and Discussion

The analysis of variance indicated that plant height and panicle length of upland rice were highly significantly ($P<0.01$) affected by the main effects of nitrogen rates, but not by phosphorous rates and their interaction (Table 2). The highest plant height was recorded at the highest nitrogen rate of 138 kg $ha^{-1}$, while the lowest plant height was recorded at the control without N application (Table 2). The highest panicle length of upland rice exhibited at the rate of 138kg $ha^{-1}$ N, which was statistically at par at the rate of 92 kg $ha^{-1}$ N (Table 2) whereas, the lowest panicle length was observed at the control without N fertilizer application. In line with the present results, Ghorbannia *et al*. (2012), Shiferaw *et al*. (2012), Riste *et al*. (2017) and Molla and Sofonyas (2018) reported significant effects of N application on plant height and panicle length. Shiferaw *et al*. (2012) observed higher plant height (113.9 cm) at 92 kg which was statistically at par (113.5 cm) with 138 kg N $ha^{-1}$.The increase in plant height of upland rice in response to the increase of N fertilizer rates was probably due to enhanced availability of N, which enhanced further cell division and more leaf area that in turn resulted in higher photo assimilates and thereby resulted in more dry matter accumulation (Shiferaw *et al*. 2012). Similarly, Ghorbannia *et al*. (2012) observed that shorter plant height (105.4 cm) was noted at the control without N fertilizer application. On the contrary, they observed also longer height of 109.3 and 111.3 cm at 50 and 100 kg N $ha^{-1}$, respectively. Riste *et al*. (2017) stated that highest and significant panicle length (27.06 cm) was recorded with application of fertilizer dose at 60 kg N$ha^{-1}$compared to the control without N fertilizer. On the other hand, Molla and Sofonyas (2018) reported longest panicles of 20.19 cm at the rate of 46 kg N $ha^{-1}$, while they noted shortest panicles in the control plots. Similar to the present results, Shiferaw *et al*. (2012) reported also the longest panicle length at the rate of 138 kg N $ha^{-1}$.

**Table 2: Combined main and interaction effects of N and P fertilizer rates on growth and yield of upland rice in three consecutive years (2015-2017) in Fogera and Libokemkem districts, northwest Ethiopia**

| N (kg/ha) | | PH | PL | TT/m2 | NFP/m2 | GY | SY | HI |
|---|---|---|---|---|---|---|---|---|
| 0 | | 57.7d | 15.7c | 395.5d | 387.8d | 1.92d | 3.08d | 38.5d |
| 46 | | 65.4c | 16.4b | 494.2c | 481.0c | 3.33c | 4.73c | 41.3c |
| 92 | | 68.5b | 17.3a | 546.5b | 536.2b | 4.59b | 5.30b | 46.4a |
| 138 | | 71.0a | 17.5a | 590.7a | 576.7a | 5.18a | 6.24a | 45.3a |
| P-value | | ** | ** | ** | ** | ** | ** | ** |
| SE± | | 4.928 | | | | | | |
| $P_2O_5$ (kg/ha) | | | | | | | | |
| 0 | | 64.8 | 16.7 | 492.2b | 483.2b | 3.66b | 4.69 | 43.8 |
| 46 | | 66.7 | 16.7 | 503.4ab | 490.4ab | 3.93a | 5.05 | 43.8 |
| 92 | | 65.5 | 16.8 | 524.6a | 512.6a | 3.67b | 4.77 | 43.5 |
| P-value | | ns | Ns | * | * | ** | Ns | ns |
| SE± | | 4.928 | 1.0212 | 67.119 | 66.894 | 0.44946 | 1.525 | 8.5871 |
| N (kg/ha) | $P_2O_5$ (kg/ha) | | | | | | | |
| 0 | 0 | 58.0 | 16.1 | 380.4 | 373.7 | 1.9f | 3.0c | 40.3 |
| | 46 | 58.2 | 15.7 | 393.8 | 386.2 | 1.9f | 3.1c | 37.7 |
| | 92 | 56.8 | 15.3 | 412.2 | 403.5 | 2.0f | 3.2c | 40.1 |
| 46 | 0 | 64.2 | 15.8 | 436.0 | 430.3 | 3.3e | 4.bc | 41.8 |
| | 46 | 69.2 | 16.7 | 539.9 | 514.5 | 3.5e | 5.5ab | 41.5 |
| | 92 | 62.7 | 16.7 | 506.7 | 498.2 | 3.2e | 4.1bc | 46.1 |
| 92 | 0 | 69.2 | 17.7 | 570.6 | 559.3 | 4.6cd | 5.5ab | 46.9 |
| | 46 | 67.3 | 16.7 | 528.4 | 519.7 | 4.9abc | 5.0ab | 51.1 |
| | 92 | 69.1 | 17.6 | 540.6 | 529.5 | 4.3d | 5.5ab | 45.0 |
| 138 | 0 | 67.7 | 17.3 | 581.8 | 569.4 | 4.9c | 5.6ab | 51.5 |
| | 46 | 72.0 | 17.5 | 551.6 | 541.3 | 5.5a | 6.5a | 47.1 |
| | 92 | 73.3 | 17.6 | 638.8 | 619.4 | 5.2ab | 6.6a | 45.4 |
| P-value | | ns | Ns | * | ns | ** | * | ns |
| SE± | | 4.928 | 1.0212 | 67.119 | 66.894 | 0.44946 | 1.525 | 8.5871 |
| CV (%) | | 7.5 | 6.1 | 13.2 | 13.5 | 11.97 | 23.5 | 19.3 |

PH = plant height (cm), PL = panicle length (cm), TT/m2 = total tillers/$m^2$, NFP = number of fertile panicles/$m^2$, Gy = grain yield (t $ha^{-1}$), SY = straw yield (t $ha^{-1}$), HI = harvest index (%), ** = highly significant at P<0.01, * = significant at P<0.05, ns = not significant at P≥0.05

The analysis of variance for number of total tillers and number of fertile panicles showed that the main effects of nitrogen and phosphorous on both yield components were highly significantly (P<0.01) and significantly (P<0.05), respectively. The interaction of N and P significantly (P<0.05) affected the number of tillers, but not the number of fertile panicles (Table 2). The highest number of total tillers and fertile panicles was recorded at the highest rate of 138 kg $ha^{-1}$ N while their lowest number was observed at the control without N fertilizer application (Table 2). Similarly, the highest number of total tillers and fertile panicles were exhibited at the rate of 92 kg $ha^{-1}$ $P_2O_5$, which were statistically at par at the rate of 46 kg $ha^{-1}$ $P_2O_5$. Number of total tillers was significantly responding to the interaction of nitrogen and phosphorous fertilizer applications. The highest number of total tillers was observed at the interaction of 138 kg $ha^{-1}$ N and 92 kg $ha^{-1}$ $P_2O_5$, while the lowest number of total tillers was recorded at the interaction of the controls without application of both N and P fertilizers (Table 2).In conformity with the results of the present experiment, Kumar *et al*. (2017) had reported maximum number of total and effective tillers $m^{-2}$ with application of 150 kg N and75 kg $P_2O_5$ kg $ha^{-1}$. On the other hand, Riste *et al*. (2017) reported maximum number of tillers and panicle $m^{-2}$at the rate of 120 kg N and 90 kg $P_2O_5$ kg $ha^{-1}$.

Ghorbannia *et al*. (2012) exhibited that the most fertile tiller number was obtained at the interaction of 50 kg N and 75 and 150 kg $P_2O_5$ $ha^{-1}$, while they were observed the least tiller number at the interaction of the controls with NP fertilizers. According to Molla and Sofonyas (2018), application of 69 kg N and 20 kg $P_2O_5$ $ha^{-1}$ resulted in highest number of seeds (126.9) per panicle of rice than other combination rates. Application of NP fertilizers at optimum rates might result in superior growth and development that eventually reflected with significantly superior yield attributes (Kumar *et al*., 2017; Riste *et al*., 2017). Inferior crop growth in the controls without NP applications might closely be associated with insufficient availability of NP below their optimal requirements (Riste *et al*., 2017).

Thousand seeds weight was not affected by the main and interaction of the nitrogen and phosphorous rates. In contrary, the grain yield was highly significantly ($P<0.01$) affected by the main and interaction effects of nitrogen and phosphorous (Table 2). Concerning the nitrogen rates, the highest grain yield was shown at 138 kg $ha^{-1}$ N while the lowest was noticed at 0 kg $ha^{-1}$ N. In the case of the phosphorous rates, the highest grain yield was exhibited at 92 kg $ha^{-1}$ $P_2O_5$ which are statistically at par with the vales of 46 kg $ha^{-1}$ $P_2O_5$ (Table 2). With regard to the interaction effect, the highest grain yield (5.5 t $ha^{-1}$) was obtained at 138-46 N-$P_2O_5$ kg $ha^{-1}$, which was statistically equivalent with the yield (5.2t $ha^{-1}$) of the 138-92 N-$P_2O_5$ kg $ha^{-1}$ application (Table 2).

The straw yield was highly significantly ($P<0.001$) affected by the main effect of nitrogen but not by phosphorous (Table 2). The interaction of nitrogen and phosphorous significantly ($P<0.005$) affected the straw yield (Table 4). Regarding the nitrogen rates, the highest straw yield was seen at 138 kg $ha^{-1}$ N while the lowest was noticed at 0 kg $ha^{-1}$ N. With respect to the interaction effect, the highest straw yield (6.6 t/ha) was obtained at 138-92 N-$P_2O_5$ kg $ha^{-1}$ which is statistically at par with some of the treatment combinations (Table 2). The rice harvest index was highly significantly ($P<0.001$) affected by the main effect of nitrogen but not by phosphorous and the interaction (Table 2). The highest harvest index, among the nitrogen rates was recorded for 138 kg $ha^{-1}$ N that was statistically equivalent with the value of 92 kg $ha^{-1}$ N while the lowest was noticed at 0 kg $ha^{-1}$ N (Table 2).In support of the present finding, Kumar *et al*. (2017) stated that the grain and straw yields of rice increased up to application of 150:75 N-P2O5 kg ha-1. Masni and Wasli (2019) had also reported that the grain and straw yields of upland rice were significantly affected and best at 60N and 35 kg P kg $ha^{-1}$. Molla and Sofonyas (2018) reported significantly higher grain and straw yields of upland rice at Tselemti District, north Ethiopia and the highest values were obtained in plots receiving 69 kg N $ha^{-1}$ and 30 kg P fertilizer $ha^{-1}$.The reports of Riste *et al*. (2017) revealed that paddy and straw yields of rice were influenced significantly ($p < 0.05$) under various combinations of N and P levels. The authors further explained that the treatment where N and P were integrated at the rate of 120 and 90 kg ha-1 exhibited the highest paddy yield (4.5 t $ha^{-1}$) which was 56% more over control. Riste *et al*. (2017) has further described that highest straw yield (9.7t $ha^{-1}$) was recorded at 150 kg N + 75 kg $P_2O_5$ $ha^{-1}$.

The better grain and straw yields at the higher rates of N and P nutrients may be attributed to the fact that application of fertilizer may have resulted in optimum levels of nutrients for crop uptake and translocation to sink thereby expressing superior crop growth and development (Riste *et al*., 2017). Similar with the observation of highest harvest index at the current experiment, Worou *et al*. (2017) had reported higher HI (0.31) of upland NERICA rice with fertilizer (N at 80 kg $ha^{-1}$ as urea combined with P at 80 kg $P_2O_5$ $ha^{-1}$) than without fertilizer (0.21). Higher grain yields in the fertilizer treatments were associated with higher harvest index.

The analysis of the Agronomic Efficiency (AE) for the nitrogen indicate that the maximum AE of 29.74 was exhibited at 46 kg $ha^{-1}$ N, then the AE reduce to 13.92 at 92 kg $ha^{-1}$ N, and become lowest (4.32) at 138 kg $ha^{-1}$ N (Table 3). AE N is usually higher at low N rate than at high N rate (Gewaily *et al*., 2018; Yasuhiro *et al*., 2019). In tropical Asia, with proper crop and water management, AEN should be typically in the range of 20–25 kg $kg^{-1}$ (Yasuhiro *et al*., 2019). Yoshida (1981) estimated better agronomic N use efficiency to be 15–25 kg rough rice per kg applied N in the tropics. Peng *et al*. (2010) reported that agronomic N use efficiency was 15 to

18 kg $kg^{-1}$ N in the dry season in the farmers' fields in the Philippines. In China, agronomic N use efficiency was 15–20 kg $kg^{-1}$ N from 1958 to 1963 and declined to only 9.1 kg $kg^{-1}$ between 1981 and 1983 (Peng *et al*., 2010). Since then, agronomic N use efficiency has further decreased in China because of the increase in N rate (Peng *et al*., 2010). Generally, fertilizer N use efficiency of ice at the highest rate is relatively low due to loss of applied N through leaching, volatilization and denitrification, which necessitate the need for improved N fertilizer practices to reduce environmental impacts and increase economic benefits of N fertilization (Fageria and Baligar, 2001). The lower agronomic efficiency at the highest N rates in the current experiment indicate that emphasis should be given to efficient nitrogen application methods like the split applications, use of slow N releasing fertilizer sources and real time N management so as to reduce the wastage of N in the upland rice production system of the study area.

**Table 3: Agronomic efficiency (AE) of nitrogen**

| N (kg/ha) | Grain Yield (kg/ha) | AE |
|---|---|---|
| 0 | 1920 | |
| 46 | 3288.261 | 29.74 |
| 92 | 4569.13 | 13.92 |
| 138 | 5166.087 | 4.32 |

Following the CIMYYT (1988) partial budget analysis method, grain and straw yield adjustments, calculations of total variable costs (TVC), gross benefits (GB) and net benefits (NB) were performed (Table 4). Dominance analysis was carried after arranging the treatments in their order of TVC. A treatment will be considered as dominated if it has higher TVC but lower NB than a previous treatment with lower TVC and higher NB (Table 5). Non-dominated treatments were taken out and marginal rate of return (MRR) was computed (Table 8). According to the CIMYYT (1988) partial budget analysis methodology, treatments exhibiting the minimum or more MRR (>100%) will be considered for the comparison of their NB. Highest NB (Birr 68,307.5$ha^{-1}$) with acceptable level of MRR (668.5%) was observed at 138-46 N-$P_2O_5$ kg $ha^{-1}$ (Table 6). In agreement to the present finding Irfan *et al*. (2016) reported that rice genotypes performed efficiently at 120 kg N + 90 kg $P_2O_5$ $ha^{-1}$ where highest paddy yield, net production value and profit were obtained. The combined application of nitrogen and phosphorous at 138-46 N-$P_2O_5$ kg $ha^{-1}$ is the most profitable rate to be recommended for rice production in Fogera plain.

**Table 4: Results of grain and straw yield adjustments, total variable cost, gross and net benefit analysis**

| N (kg/ha) | $P_2O_5$ (kg/ha) | TVC (Birr/ha) | GY (t/ha) | SY (t/ha) | AGY (t/ha) | ASY (t/ha) | GB (Birr/ha) | NB |
|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 0.0 | 1.8867 | 2.9533 | 1.69803 | 2.658 | 26112.969 | 26113.0 |
| 0 | 46 | 1731.1 | 1.9133 | 3.0933 | 1.72197 | 2.784 | 26587.359 | 24856.3 |
| 0 | 92 | 3462.1 | 1.9733 | 3.1867 | 1.77597 | 2.868 | 27417.231 | 23955.1 |
| 46 | 0 | 1310.0 | 3.2533 | 4.6 | 2.92797 | 4.14 | 44495.595 | 43185.6 |
| 46 | 46 | 2386.1 | 3.5133 | 5.5133 | 3.16197 | 4.962 | 48640.959 | 46254.9 |
| 46 | 92 | 3462.1 | 3.2267 | 4.0733 | 2.90403 | 3.666 | 43603.569 | 40141.5 |
| 92 | 0 | 2620.0 | 4.62 | 5.4467 | 4.158 | 4.902 | 62015.436 | 59395.4 |
| 92 | 46 | 3696.1 | 4.8867 | 4.9733 | 4.39803 | 4.476 | 64744.569 | 61048.5 |
| 92 | 92 | 4772.1 | 4.26 | 5.4933 | 3.834 | 4.944 | 57691.764 | 52919.7 |
| 138 | 0 | 3930.0 | 4.8533 | 5.6267 | 4.36797 | 5.064 | 65044.431 | 61114.4 |
| 138 | 46 | 5006.1 | 5.4533 | 6.5333 | 4.90797 | 5.88 | 73313.559 | 68307.5 |
| 138 | 92 | 6082.1 | 5.2333 | 6.5667 | 4.70997 | 5.91 | 70676.631 | 64594.5 |

TVC= Total Variable Cost, GY=Grain Yield, SY= Straw Yield, AGY= Adjusted Grain Yield, ASY= Adjusted Straw Yield, GB= Gross Benefit, NB= net benefit

**Table 5: Result of dominance analysis**

| N (kg/h | $P_2O_5$ (kg/ha) | TVC (Birr/ha) | NB | Dominance |
|---|---|---|---|---|
| 0 | 0 | 0 | 26,112.97 | |
| 46 | 0 | 1310 | 43,185.60 | |
| 0 | 46 | 1731.053 | 24,856.31 | D |
| 46 | 46 | 2386.053 | 46,254.91 | |
| 92 | 0 | 2620 | 59,395.44 | |
| 0 | 92 | 3462.105 | 23,955.13 | D |
| 46 | 92 | 3462.105 | 40,141.46 | D |
| 92 | 46 | 3696.053 | 61,048.52 | |
| 138 | 0 | 3930 | 61,114.43 | |
| 92 | 92 | 4772.105 | 52,919.66 | D |
| 138 | 46 | 5006.053 | 68,307.51 | |
| 138 | 92 | 6082.105 | 64,594.53 | D |

D= Dominated

**Table 6: Result of Marginal rate of return (MRR) analysis**

| N (kg/h | $P_2O_5$ (kg/ha) | TVC (Birr/ha) | NB | MRR (%) |
|---|---|---|---|---|
| 0 | 0 | 0 | 26,113 | |
| 46 | 0 | 1310 | 43,185.6 | 1303.3 |
| 46 | 46 | 2386.1 | 46,254.9 | 285.2 |
| 92 | 0 | 2620 | 59,395.4 | 5618.0 |
| 92 | 46 | 3696.1 | 61,048.5 | 153.6 |
| 138 | 0 | 3930 | 61,114.4 | 28.2 |
| 138 | 46 | 5006.1 | 68,307.5 | 668.5 |

## 4. Conclusions and Recommendation

The national average yield of rice in Ethiopia is about 2.8 t $ha^{-1}$, which is lower compared to the world average productivity of 4.6 tones $ha^{-1}$. Soil nutrient deficiencies and terminal moisture stress are among the major causes of the low rice productivity. Based on the results of the present study the highest grain yield and economic profitability of rice was obtained by the application of 138-46 N-$P_2O_5$ kg $ha^{-1,}$ which can be recommended for rain fed upland rice production in the study area and other similar agro-ecologies. Future research works towards the improvement of nitrogen use efficiency of rice are also recommended.

**Conflict of Interest**

The authors declare that there is no conflict of interest

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# Comparative Evaluation of On-Farm Growth Performance of Local Gamo Highland and Gamo X Bonga F1 Crossbred Sheep in Chencha District, South Ethiopia

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Received: September 9, 2019 Accepted: November 7, 2019

**Abstract:** *The study was conducted to compare the on-farm growth performance of local Gamo highland and Gamo x Bonga first filial generation (F1) crossbred sheep in Chencha district. A total of 93 local Gamo highland and 125 Gamo x Bonga F1 crossbred sheep were used for data analysis. The study revealed that the overall mean growth performance of local Gamo highland sheep for birth, weaning, six-month, nine-month and yearling weights were 2.12±2.20, 8.84±1.38, 14.40±1.73, 19.17±0.99 and 22.95±1.20 kg, respectively. The corresponding parameters up to six-month weight for Gamo x BongaF1 crossbred were 2.77±0.65, 15.01±2.39 and 22.75±2.08 kg, respectively. Crossbred sheep performed better than local Gamo highland sheep at respective growth stages and attained early at six-month weight the yearling weight of local Gamo highland sheep's market weight. Males showed higher values than females at all growth stages in general. The overall mean daily weight gain (g day$^{-1}$) of pre and post-weaning for local Gamo highland sheep were 74.7±9.1 and 52.3±0.7, respectively. The corresponding values (g day$^{-}$1) for Gamo x Bonga crossbred were 136.0±19.3 and 86.0±3.4, respectively. The growth rate of Gamo x BongaF1 crossbred sheep were faster at both pre and post-weaning than local Gamo highland sheep. Hence, it is possible to conclude that crossbreeding of local Gamo highland sheeph as improved sheep productivity in the study area.*

**Keywords:** Birth weight, Chencha, crossbred sheep, local Gamo highland sheep, weight gain



## 1. Introduction

There are about 14 traditionally recognized sheep populations in Ethiopia, which are classified into nine genetically distinct breeds (Gizaw, 2008). The country has about 30.7 million heads of sheep, of which about 75% is found in the highlands where mixed crop-livestock production systems dominate (DAGRIS, 2006; CSA, 2017). Sheep production is among the most important agricultural activities in the mixed perennial crop (*Enset; Ensete ventricosum*) like Gamo highland areas and providing cash income from the sale of live animals, as insurance during crop failure, source of meat, and manure in Southern Ethiopia (Kocho, 2007).

However, sheep genetic improvement programs for local sheep breeds by crossbreeding with exotic breeds in developing countries like Ethiopia have not been very successful due to unsuitability of the exotic breeds with the breeding objectives and management approaches in low-input and low-output production systems (Workneh *et al*., 2003; Kosgey *et al*., 2006). In addition, poor performance of imported breeds from the temperate regions to tropical region with sub-optimal management conditions and high importation cost has created a negative image for genetic improvement programs (Workneh *et al*., 2003). Further, crossbreeds with exotics in Ethiopia were rejected by farmers upon dissemination because of sustainability of parent stock, high management and phenotypic unlikeness like Dorper sheep to the indigenous ones (Markos, 2006; Getachew *et al*., 2016). In Ethiopia, past failures in sheep genetic improvement have led to new research design of breeding programs like community-based breeding program. It properly considers the farmers' breeding objectives, infrastructure and ownership and active participation from inception through implementation in situations where livestock keepers already run their animals together, such as in communal grazing areas (Sölkner-Rollefson, 2003; Solomon *et al*., 2009; Solomon *et al*., 2010; Gemeda, 2011; Solomon *et al*., 2011; Tadele, 2011). This program has a potential to produce improved indigenous sheep breeds so that local animals can replace the genetic potential of exotic breeds for tropical environments like Ethiopia.

Bonga sheep breed is one of the known Ethiopian indigenous sheep breeds produces at (1800 – 2835 m.a.s.l) and developed by community-based sheep breeding program initiated by International Center for Agricultural Research in the Dry Areas (ICARDA) project (Gizaw, *et al*., 2013) and strengthening now by the government support. Sheep populations around Gamo highland are relatively characterized lighter and dwarf and with short tail (Aberra *et al*., 2013) than Bonga (Zewdu, 2008).However, its productivity in other similar agro-ecologies like Gamo highland areas was not well documented to replace the exotic genotypes. There is an uncontrolled dissemination trend of unknown rams like sheep from Dawuro Zone in south Ethiopia by different aid organizations for crossbreeding in the current study areas. However, the on-farm performance of the existing sheep ecotype and BongaF1 crossbreds was not done and recorded. Thus, the current research was prepared to evaluate the comparative on-farm growth performance of both local Gamo highland and their F1 crossbred lambs with Bonga rams and to devise possible breeding intervention options in the study area.

## 2. Material and Method

### 2.1. Study area

The study was conducted in Chencha district, Gamo zone. Chencha is bordered on the south by Arba Minch Zuria, on the west by Dita, on the north by Kucha and on the east by Ego districts. It is located 37 kilometers north of Arba Minch. Chencha has a longitude and latitude of 6°15′N, 37°34′E, respectively and an elevation of 2732 meters above sea level. The average annual temperature is 16°C. The area is characterized by mixed farming system. The major crop types produced include inset, barley, wheat, bean, pea and potatoes.

### 2.2. Sampling method

Chencha district was selected purposively among Gamo highland areas for its high population of sheep (10,760 head) as indicated by Office of Livestock and Fishery (unpublished). Sheep keeping trend is decreasing due to pastureland shortage. Based on farmers' requirement to improve the productivity of the local sheep, crossbreeding of the local sheep with other productive breeds was thought to be a solution. Hence, Bonga sheep breed was also purposively selected for crossbreeding for its big body size and fast growth rate than local Gamo highland sheep population. Accordingly, volunteer nearby households those who have ewes were established as ram user groups.

### 2.3. Sheep management

About 10 yearling improved Bonga rams were distributed for ram user groups. Sheep in the study areas depend largely on communal grazing by tethering. The disseminated rams were supplemented with locally available feed sources (barley, inset and home leftovers) along with grazing by tethering.

**Figure 1: Local Gamo highland sheep eco-type grazing by tethering.**

### 2.4. Mating method

Bonga rams improved by community-based breeding program through paternal line selection from Bonga agricultural research center (village cooperatives) were introduced for crossbreeding with local ewes by natural mating based on 1:25-30 male to female mating ratio. Ram user groups were well trained to keep ewes separately only to mate with improved Bonga rams and bring their breeding ewes when they show heat sign at any day time. Then, ewes were allowed for hand mating with improved Bonga rams at mating station.

### 2.5. Data collection procedure

Data collected were lamb breed, sex and weight (from birth to yearling every three months interval) for both breeds (local Gamo highland sheep and Bonga x Gamo F1 crossbred sheep). The effect of birth type and parity were not considered in the current study due to almost all the lambs born were single (small breeds are less prolific than the very large breeds (Gizaw *et al*., 2013)) and sheep owners were not sure for their ewe parity, respectively. Sheep owners were trained to report to the trained data collector on daily basis in order to weigh the lambs and record all necessary parameters.

### 2.6. Data analysis

The lamb data were analyzed only for available data due to the high off-take rate to the market and some mortality. The collected data were analyzed using SPSS software(version 16.0). The response variables in the analysis were weights at different age categories and pre- and post-weaning growth rates. The fixed effects considered were the breed and sex of the lambs.

The model used to analyze the data is indicated below.

$$Yij = \mu + Bi + Si + \varepsilon ij \qquad [1]$$

Where

- Yij = the responses of birth, weaning, six-month, nine-month, and yearling weights
- μ = the overall mean
- Bi = fixed effect of $i^{th}$ breed (1= local Gamo highland sheep, Bonga x GamoF1 crossbred sheep)
- Sj = fixed effect of $j^{th}$ sex (1= male, 2= female)
- εij = random error

## 3. Results and Discussion

### 3.1. On-farm growth performance

The on-farm growth performance of local Gamo highland sheep and Gamo x BongaF1 crossbred sheep is presented in Table 1. The overall growth performance of local Gamo highland sheep for birth, weaning, six-month, nine-month and yearling weights were 2.12±2.20, 14.40±1.73, 19.17±0.99 and 22.95±1.20 kg, respectively.

The birth weight of the local sheep recorded in the present study was generally lower than the findings of different researchers in different parts of the country. Accordingly, Lakew *et al.* (2013) in Eastern Amhara, Berhanu and Aynalem (2009) in Western Ethiopia indigenous sheep and Mekuriaw *et al.* (2013) in Farta and Washera recorded the birth weights of 2.36 kg,2.45±0.40kg, 2.50±0.02 kg and 2.61±0.0 kg, respectively. The result of three-month weight for local Gamo highland sheep (8.84±1.38) was comparable with reports of Lakew *et al*. (2013) and Zelalem (2018), but lower than that of Hassen *et al*. (2002) for local sheep group. On the other hand, the six-month body weight of local lambs (14.40±1.73 kg) recorded in the present study was higher than the findings of Zelalem (2018)which was 13 ± 0.8 kg for local breed.

The yearling weight of local Gamo highland sheep (22.95±1.20 kg) recorded in the present study was higher than Farta (20.08 ± 0.7) and Menz sheep, which were reported by Shigdaf (2011) and Gizaw *et al. (*2008a). However, the yearling weight observed was lower than the findings of Gizaw *et al.* (2008a) which was recorded by pure Bonga (27.8 ± 1.5) and Washera (23.6 ± 0.7). Similarly, the results were lower than the findings of Abegaz and Gemeda (2000) for Horro sheep (23.7 ± 0.04).

The birth, weaning and six-month weights of Gamo x Bonga F1 crossbred sheep were 2.77±0.65, 15.01±2.39 and 22.75±2.08 kg, respectivelyas presented in Table 1. The birth weight of Gamo x Bonga F1 crossbred (2.77±0.65 kg) was higher than the findings of other researchers where Deribe *et al.* (2017) reported 2.55 ± 0.63 kg for Dorper cross lambs and Mekuriaw *et al.* (2013) found 2.59±0.01kg for Washera and Farta crossbreed lambs. However, the birth weight of the local Gamo highland sheep was lower compared to thepure Bonga sheep breed (3.42 kg) as reported by Haile *et al.* (2014). Similar results were also reported byMetsafe (2015) where pure Bonga sheep breed weighed 3.6 kg at birth.

The weaning weight of Gamo x Bonga F1 crossbred (15.01±2.39 kg) was higher than Washera and Farta crosses [11.17±0.49 kg] (Mekuriaw *et al.*, 2013). On the other hand, it has comparable weaning weight with Dorper x local cross [14.95±0.21] (Lakew *et al.,* 2013) and Pure Bonga [14.8±0.2] (Aynalem *et al*., 2014). The weaning weight of Gamo x Bonga F1 crossbred was however lower than the findings of Metsafe (2015) who reported 15.5±0.08 kg for pure Bonga.

The body weight of Gamo x Bonga F1 crossbred recorded at six-month (22.75±2.08 kg) was generally greater than those reported by Mekuriaw *et al.* (2013), Hassen *et al.* (2002) and Gizaw *et al.* (2013) for Farta x Washera, Awassix local crosses and Awassi x Menz, respectively.

Generally, the findings of the present study revealed thatGamo x Bonga F1 crossbred performed better than local sheep at respective growth stages. Additionally, crossbred sheep had attained the yearling weight of local Gamo sheep early at six-month growth stage which will be associated with the effect of heterosis. Moreover, on-farm performances of both study sheep were affected by sex. Except for birth and yearling weights, males of local Gamo highland sheep were relatively heavier than the females. On the other hand, in crossbred sheep, males recorded higher weights than females at all growth stages.

**Table 1: On-farm growth performances of local Gamo highland and Gamo x Bonga F1 crossbred sheep in Chencha district**

| Sheep breed | Effect | N | BW (mean±SD) | WW (mean±SD) | 6MW (mean±SD) | 9MW (mean±SD) | Yearling (mean±SD) |
|---|---|---|---|---|---|---|---|
| | Sex | | * | * | * | | |
| G | Overall | 93 | 2.12±2.20 | 8.84±1.38 | 14.40±1.73 | 19.17±0.99 | 22.95±1.20 |
| | Male | 41 | 2.44±3.30 | 8.72±1.30 | 14.33±1.88 | 19.16±0.89 | 23.03±1.03 |
| | Female | 52 | 1.87±0.21 | 8.96±1.46 | 14.45±1.62 | 19.18±1.10 | 22.91±1.32 |
| G x B | Overall | 125 | 2.77±0.65 | 15.01±2.39 | 22.75±2.08 | - | - |
| | Male | 63 | 2.80±0.67 | 14.99±2.45 | 24.50±1.51 | - | - |
| | Female | 62 | 2.72±0.63 | 11.06±2.36 | 21.35±1.22 | - | - |
| | Breed | | * | * | * | | |
| | G | 93 | 2.12±2.20 | 8.84±1.38 | 14.40±1.73 | 19.17±0.99 | 22.95±1.20 |
| | G x B | 125 | 2.77±0.65 | 15.01±2.39 | 22.75±2.08 | - | - |

*P<0.05, G= Local Gamo highland sheep, B x G= Gamo x BongaF1 crossbred sheep, N=number of observations, BW= birth-weight, WW= weaning-weight, 6MW= six-month weight, 9MW= nine-month weight, SD= standard deviation

## 3.2. Growth rate

The pre-and post-weaning growth rate of local Gamo highland sheep and their crossbreds with Bonga rams sheep is presented in Table 2.The overall growth rate (g day$^{-1}$) of pre and post-weaning growth rate of local Gamo highland sheep were 74.7±9.1 g day$^{-1}$and 52.3±0.7g day$^{-1}$, respectively. The current finding of pre-weaning daily average weight gain for local Gamo highland sheep was higher than the report of Zelalem (2018) for local breeds (64.8± 5.5 and 63.4± 4 g day$^{-1}$) whereas post-weaning daily average weight gain was lower under similar management conditions. The rate of daily weight gain of Gamo highland sheep at pre-weaning was faster than those at post-weaning. Female sheep (78.8 g day$^{-1}$) showed faster weight gain during pre-weaning than males (69.8 g day$^{-1}$), while male sheep (53.0 g day$^{-1}$) gained weight rapidly during post-weaning than the females (51.7 g day$^{-1}$).

The overall growth rate of pre and post-weaning for BongaF1 crossbred sheep was136.0±19.3 and 86.0±3.4 g day$^{-1}$, respectively as presented in Table 2. The current findings of pre-weaning daily average weight gains for crossbreed was higher than the findings of other researchers (Deribe *et al.*, 2017, Mekuriaw *et al.*, 2013) where Zelalem (2018) reported weight gain of 92.2± 5.4 g day$^{-1}$for local breed. Comparable post-weaning daily average weight gains for crossbreed were reported by Zelalem (2018) for local breeds (86 ± 4 g day$^{-1}$) under similar management conditions. However, lower findings reported by Lakew *et al.* (201) for Dorper X local crosses and Aynalem *et al.* (2014) for Bonga. Generally, Bonga F1 crossbred sheep pre-weaning weight gain rate recorded in the present study was faster than the post-weaning rate which could be attributed to weaning shock. Similarly, males (135.4 g day$^{-1}$) showed faster weight gain during pre-weaning than females (92.7 g day$^{-1}$), but females (114.3 g day$^{-1}$) revealed rapid weight gain during post-weaning than males (105.7 g day$^{-1}$).

The current study revealed that crossbred F1 sheep were faster in weight gain during both pre and post-weaning than local Gamo highland sheep. The possible reason for this may be the hybrid vigor effect of crossbreds. Therefore, the superior daily average body weight gain of Bonga F1 crosses over local sheep attracts farmers in the study area to use Bonga sheep breed as one of the parent stocks.

**Table 2: Weight gain of local Gamo highland and Gamo x Bonga F1 crossbred sheep in the study area**

| Sheep breed | Effect | N | Pre-weaning (mean±SD g day$^{-1}$) | Post-weaning (mean±SD g day$^{-1}$) |
|---|---|---|---|---|
| | Sex | | * | * |
| G | Male | 41 | $69.8\pm22.2^{b}$ | $53.0\pm1.0^{a}$ |
| | Female | 52 | $78.80\pm13.90^{a}$ | $51.7\pm0.5^{b}$ |
| G x B | Male | 63 | $135.4\pm19.8^{a}$ | $105.7\pm10.4^{b}$ |
| | Female | 62 | $92.7\pm19.2^{b}$ | $114.3\pm12.7^{a}$ |
| | Breed | | * | * |
| | G | 93 | $74.7\pm9.1^{b}$ | $52.3\pm0.7^{b}$ |
| | G x B | 125 | $136.0\pm19.3^{a}$ | $86.0\pm3.4^{a}$ |

$^{*}$P<0.05, G = Local Gamo highland sheep, G x B = Gamo x Bonga F1 crossbred sheep; N= number of observations, SD = standard deviation

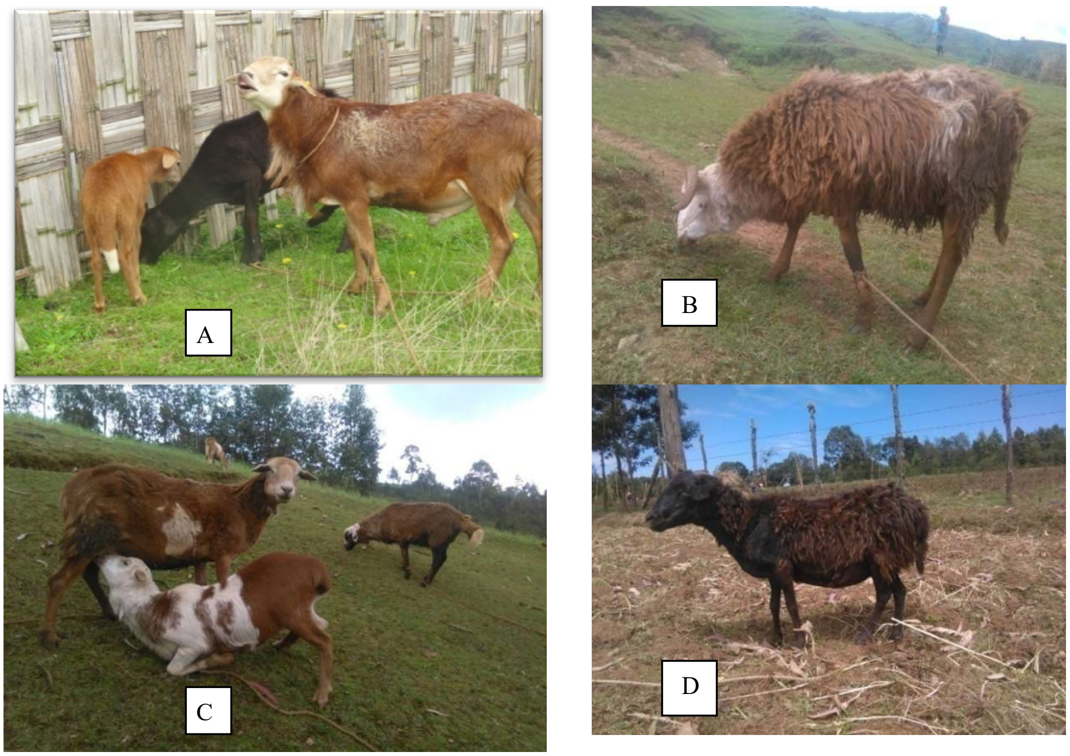


**Figure 2: Local Gamo highland sheep and Gamo x Bonga F1 crossbred sheep in the study areas**

A = Improved Bonga ram with FI lamb; B = Typical local Gamo highland ram; C = local Gamo highland ewe with 3 months crossbred F1 lamb; D = Typical local Gamo Highland ewe

## 4. Conclusions and Recommendation

In the current findings, on-farm growth performance of both study sheep was affected by both sex and breed. Males revealed higher values than females at growth stages for both sheep breeds in general. This could be due to sex affected genes for males. Gamo x BongaF1 crossbred sheep breed showed better growth performances than local Gamo highland sheep at birth, weaning and six-month weights.

The weight gain rate for pre-weaning was faster than post-weaning rate. Weaning shock and management could be factors for lower weight gain at post-weaning. The study revealed that Bonga crossbred F1 sheep were faster in weight gain at both pre and post-weaning than local Gamo highland sheep. This could be attributed with genetic effect of Bonga sheep breed. To improve local Gamo highland sheep productivity in terms of attaining at early market weight, finisher crossbreeding with improved Bonga rams was recommended in the study area.

**Conflict of Interest**

The authors declared that there is no conflict of interests.

**Acknowledgement**
The authors would like to thank Southern Agricultural Research Institute (SARI) for funding and Arba Minch Agricultural Research Center (AMARC) for facilitating the field research works.

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# Trade Mapping of India's Cotton Export

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Received: August 31, 2019 Accepted: February 26, 2020

Abstract: The present research empirically investigated the export comparative advantage of India's cotton products and determined the potential target importing cotton markets using annual dated data sourced from FAO database, spanning from 2000 to 2013.The collected data were analyzed using the static revealed comparative indexes, neoclassical comparative index (Trade mapping analysis), market structure index (Herfindahl-Hirschman Index) and prioritization index models. The results of the findings showed that India has poor comparative advantages with the exception of cotton lint in the exportation of its cotton products due to specialization in the production of lint. However, from the sector point of view the country had revealed comparative advantage in the exportation of cotton. Furthermore, empirical evidence showed that the cotton lint been the major export earning India emerged in the export market over the study period despite commanding small share in the market, and is among the winner groups. Though, for the overall sector, the country is at a threshold in the export market and among the winner groups. Therefore, study recommends the need for increase productivity and production cut-costs in order to improve the position of its products export amongst the commercial competitors. In addition, the commercial production status and behavior of the major competing exporting countries (China and USA) need to be fully tracked or monitored by the major participants in the cotton value chain in other to deal with the effects of externalities. The research will help to breach the gap of India's cotton share in the global market by exploring potential target markets for its product, thus enhancing its cotton foreign exchange earnings.

Keywords: Cotton export, comparative advantage; India, target market, trade mapping



## 1. Introduction

Cotton is one of the most important textile fibers in the world, accounting for 35% of the world fiber use. Cotton was first cultivated in the old world about 7,000 years ago, by the inhabitants of the Indus Valley Civilization. This civilization covered a huge swath of the north-western part of the India subcontinent, comprising today parts of eastern Pakistan and north-western India (Samuel et al., 2015).

Among the countries in which cotton is an important contributor to rural livelihoods are China, India and Pakistan where millions of rural households are engaged in cotton production and more than two- thirds of the world's cotton is produced in the developing countries (Baffes, 2005). Despite that India is the second largest producer of cotton in the world after China with world share contribution of 22% (International Trade Centre, 2013); the country has been more or less non-existent in the world cotton market.

Recognizing potential target markets and prioritizing them for a particular product can eventually be useful in developing efficient marketing strategies related to policy makers. Due to the manifold and profitability of global transactions, benefits of joining the globalization process cannot be over-emphasized. To enter this stream, evaluation of competitiveness levels is necessary. Batra and Khan (2009) reported that there is an emerging concern and ongoing discussion among the less developed countries about the threats of increasing exports share of some robust economies and the consequent intensification of competition among manufactures. Therefore, taking steps to keep and even increase the market performance by identifying and prioritizing the potential target markets is an important matter. Literature review of similar studies (Sharma and Bugalya, 2014; Kumar and Singh, 2015; Samuel *et al*., 2015; Dhima and Sharma, 2017; Gupta and Khan, 2017) showed no comprehensive study on the current status of importing potential target markets for India's cotton. Hence, identifying potential target markets and prioritizing them for export direction of India's cotton export can help to find the best strategies for companies that export India's cotton. Furthermore, policymakers can make use of the business information strategies, especially in bilateral trade negotiations. Therefore, the objectives of this research are to determine India's cotton export growth and competitiveness in the global cotton markets; compare India's cotton export growth to global demand; and, to identify and prioritize the potential target importing cotton markets for India's cotton export.

## 2. Research Methodology

The study used annual dated time series data sourced from the FAO database, spanning from 2000 to 2013. The data covered export value of all the cotton products sub-sectors *viz.* cotton lint, cotton linter, cotton waste, cotton carded/combed and cotton seeds. The first objective was achieved using revealed comparative advantage (RCA) index, revealed symmetric comparative advantage (RSCA), export competitiveness index (XCI) and revealed trade advantage (RTA). The second objective was achieved using Trade mapping analysis (TMA); the third objective was achieved using prioritization index; and, the last objective was achieved using Herfindahl-Hirschman Index (HHI). The empirical models are given below.

### 2.1. Indexes of export's revealed comparative advantage

Following Balassa (1965) as cited by Astaneh *et al.* (2014); Gupta and Khan (2017); Navghan *et al.* (2017) the revealed comparative advantage (RCA) was calculated following the equation below.

$$RCA_{ij} = \frac{X_{ij}/\sum X_{ij}}{X_{iw}/\sum X_{iw}} \qquad [1]$$

Where,

$RCA_{ij}$ = revealed comparative advantage of i$^{th}$ commodity by country j

$X_{ij}$ = Export of i$^{th}$ commodity by country j
$\sum X_{ij}$ = Total export of i$^{th}$ commodity class by country j
$X_{iw}$ = Export of i$^{th}$ commodity by the world
$\sum X_{iw}$ = Total export of i$^{th}$ commodity class by the world

The numerator represents the commodity structure of the exports from j$^{th}$ country and the denominator represents the product structure of the global market. The range of *RCA* is between 0 to∞. *RCA*> 1 shows sectors in which a country is relatively more specialized and *vice versa* (the more the value of the index, the greater reliability and the better the given position). In other words, if RCA >1, then the state has a revealed comparative advantage in the commodity; if RCA <1, then the state has a revealed comparative disadvantage in the commodity; and, RCA=1, implies comparative neutrality.

The benefit of comparative advantage index is that it takes into consideration the intrinsic advantage of a particular export commodity as well as the consistency with changes (Batra and Khan, 2009). However, one of the main disadvantages of *RCA* index is its wide range such that it is too wide to determine the degree of comparative advantage properly (Astaneh *et al.,* 2014). To solve the above problem, Laursen (1998) introduced another form of *RCA* index using a symmetric or normalized index by a homogeneous transformation called revealed symmetric comparative advantage (RSCA) as indicated below.

$$RSCA_{ij} = (RCA_{ij} - 1)/(RCA_{ij} + 1) \qquad [2]$$

These changes range between -1 and +1 so that negative values indicate no advantage and positive values indicate that there is an advantage.

The mentioned indexes are static. New indexes are expanded which have more consistency with new conception of competitive advantages. One of them is Trade Map (TM) introduced by International Trade Centre (ITC) and United Nations Conference on Trade and Development (UNCAD) and compares export growth to global demand growth. The groups of export commodities are classified into winners and losers based on *TM* and defined in Table 1. Based on the information in Table 1, if the global growth rate of import of commodity $i$($r_i$) is bigger (less)than the growth rate of aggregated imports, the market of this commodity is identified as emerging (declining) market. If the export growth rate of country $j$ for commodity $i^{th}$($d_{ij}$)is bigger (less) that the import growth rate of this commodity ($r_i$), the country is winner (looser) on that commodity.

**Table 1: Trade mapping coordinates**

| Coordinate | Property | Decision rule |
|---|---|---|
| First quarter | $d_{ij}>r_i> r$ | Winners in emerging markets |
| Second quarter | $d_{ij}<r_i> r$ | Losers in emerging markets |
| Third quarter | $d_{ij}>r_i< r$ | Winners in declining markets |
| Fourth quarter | $d_{ij}<r_i< r$ | Losers in declining markets |

Source: International Trade Centre (2013)

### 2.2. Export Competitiveness Index (XCI)

The export competitiveness pertains to the ability and performance of any product, firm, industry, or country to export in given market comparative to ability and performance of other product, firm, industry, or country. Export competitiveness of cotton products in India was used to determine its changes in the world cotton market share. Changes in Indian's cotton export share in the world cotton market over time can indicate the long-term comparative advantage of the product. It neutralizes cyclic fluctuations to large extent which showed sustained trends in the shifting of market forces toward the new center of gravity. Following Navghan *et al*. (2017) the XCI developed by Fertö and Hubbard (2002) is used to calculate export competitiveness index.

$$XCI_{ij} = \frac{X_{ijt}/X_{wt}}{X_{ijt-1}/X_{wt-1}} \quad [3]$$

Where,

$XCI_{ij}$ = *Export competitive index of ith product by country j at time 't'*

$X_{ijt}$ = *Export of ith product by country j at time 't'*

$X_{iwt}$ = *Export of ith product by the world at time 't'*

$X_{ijt-1}$ = *Export of ith product by country j at time 't-1'*

$X_{iwt-1}$ = Export of i^th^ product by the world by at time '*t-1*'

If the XCI is >1 then it can be said that the country has competitiveness in the export of $i^{th}$ product.

### 2.3. Relative Trade Advantage (RTA)

Besides using the exports as a factor, as in Balassa index, RTA has also been taken into consideration. Following Navghan *et al.* (2017) the RTA index was calculated using the formula below.

$$RTA = RXA - RMA \quad [4]$$

$$RTA = \frac{X_{ij}/\sum X_{ij}}{X_{iw}/\sum X_{iw}} - \frac{M_{ij}/\sum M_{ij}}{M_{iw}/\sum M_{iw}} \quad [5]$$

Where,

$RTA$ = relative trade advantage

*RXA = RCA or Balassa index*

*RMA = Relative import advantage*

$M_{ij}$ = *Import of ith commodity by country j*

$\sum M_{ij}$ = *Total Import of ith commodity class by country j*

$M_{iw}$ = *Import of ith commodity by the world*

$\sum M_{iw}$ = *Total Import of ith commodity class by the world*

### 2.4. Prioritization of target export markets

Following Brewer (2001), the importing countries were prioritized according to potential indices of imports using six indices.

The average imports $i^{th}$ commodity by country *j*

$$m_1 = \overline{M_{ij}} \quad [6]$$

The ratio of imports of the $i^{th}$ commodity by country *j* to total world imports of the commodity

$$m_2 = \frac{M_{ij}}{M_{iw}} \quad [7]$$

The ratio of imports of $i^{th}$ commodity by country *j* to total imports of country *j*

$$m_3 = \frac{M_{ij}}{M_j} \quad [8]$$

The index of disadvantage of country *j* for $i^{th}$ commodity

$$m_4 = \frac{M_{ij}/M_j}{M_{iw}/M_w} \quad [9]$$

The average growth of imports of $i^{th}$ commodity by country *j*

$$m_5 = r.M_{ij} \quad [10]$$

$$H_j = \sum_{k=1}^{n} \left| \frac{m_{kj} - m_j}{\delta_i} \right| / n \quad [11]$$

Where,

$m_{kj}$= Index $k^{th}$ for country $j$,

$\delta_i$= Standard deviation of indices for country j

$H_j$ = Simple average of the standardized indices of the above

Using this method, specified and limited number of countries, whose $H_j$ index is relatively the highest were selected in the final prioritization.

### 2.5. Herfindahl–Hirschman Index (HHI)

Herfindahl-Hirschman index is calculated by the summation of the squares of market shares of all active firms in the industry. This index is very similar to Hirschman index except for the square root (Hirschman, 1964).

$$HHI = \sum_{i=1}^{n} S_i^2 \quad [12]$$

Where,

Si = market share of $i^{th}$ sub-sector in the sector;

n = number of sub-sectors.

Types of market structure and characteristics as reported by Williams and Rosen (1999) are presented in Table 2.

### 2.6. Diversification Index

However, literature has shown various methods used to measure level and degree of diversification but for the present empirical examination, Berry's index and Theil's Entropy index were used.

*Berry's Index of Diversification (BID)* = *1-* $\sum_{i=1}^{n} P_{it}^2$
[13]

$$P_{it} = \frac{A_{it}}{\sum_{i=1}^{n} A_{it}} \quad [14]$$

Where,

$P_{it}$ = Share contribution of $i^{th}$ sub-sector to the main sector at time ‘t’

$A_{it}$ = $i^{th}$ Export value of ith sub-sector at time ‘t’

$\sum_{i=1}^{n} A_{it}$ = Export value of cotton sector at time ‘t’

The value of Berry's index varies between zero and one. It is one (1) in case of perfect diversification and zero in case of perfect specialization.

$$\textit{Entropy Index of Diversification (EID)} = \sum_{i=1}^{n} P_{it} \log\left(\frac{1}{P_{it}}\right) \quad [15]$$

The value of Entropy index (E) varies from zero to *log n*. *'EID'* takes the value of zero in case of perfect specialization and *log n* when there is perfect diversification.

The actual degree of diversification to maximum diversification for a given sector was measured through Berry's index below.

$$\textit{Degree of diversification by Berry's Index} = \textit{Berry's Index} \Big/ \left(1 - \frac{1}{n}\right) \quad [16]$$

Where,

n = number of sub-sectors in the agriculture sector

$$\textit{Degree of diversification by Entropy Measure} = \textit{Entropy Index}/\textit{logn} \quad [17]$$

Rule of Thumb:

0 = specialization
0.01-0.19 = Very low diversification
0.20- 0.39 = Low diversification
0.40-0.59 = Moderate diversification

0.60-0.79 = High diversification
0.80-0.99 = Very high diversification
1.00 = Perfect diversification

**Table 2: Market structure**

| Market type | HHI | Feature |
|---|---|---|
| Perfect competition | HHI → 0 | None of the subsectors have considerable share in the sector |
| Monopolistic competition | (1/HHI → 10) | None of the sub-sectors had more than 10% share in the sector |
| Opened oligopoly | $6 < (1/HHI) \leq 10$ | Few subsectors account for maximally 40% share in the sector |
| Closed oligopoly | $1 < (1/HHI) \leq 6$ | Few subsectors account for maximally 60% share in the sector |
| Monopoly | HHI → 10 | One subsector account for whole share of a sector |

Source: Williams and Rosen (1999)

## 3. Results and Discussion

### 3.1. India's cotton export status

Presented in Table 3 are the export values of India's cotton sub-sectors along with their respective growth rates for the period 2000 to 2013. A perusal of the Table showed that cotton lint accounted for the highest contribution of the total export value of Indian cotton sector with a share contribution of 96.58%; an equivalent approximately export value of $21.5 billon. The contributions of the other cotton products were very marginal with the sum share contribution been 4.42%, thus negligible. Therefore, it can be inferred that cotton lint is the main export earning of India's cotton sector which is driven by wide mismatch between demand and supply in the global fabric trade market. Furthermore, it was observed that the export growth rate of the main sector and the sub-sectors were plagued or accompanied by fluctuation with the fluctuations been more pronounced in the cotton carded/combed, cotton seeds and cotton linter in descending order. However, empirical evidence showed mild fluctuation rate in the lint and waste sub-sectors and the main sector during the period under study.

The average annual growth rate of cotton carded/combed was found highest despite been poor in the share contribution of India's cotton export value and accompanied high level of fluctuation. However, evidence showed that export value recorded for the sub-sector during the year 2003 was responsible for the heightened annual average growth rate. The average share of India's cotton in the total world cotton to the tune of 10.03% is low and this may be attributed to high domestic consumption as well as subsidies devised by the competitive major exporters (China and USA) which dampen the price of India's cotton products.

### 3.2. RCA and RSCA indices of India's cotton export

The year-wise results of export's revealed comparative advantage of India's cotton sector calculated by RCA and RSCA indices over time indicated that India had good and fair export revealed comparative advantage in the exportation of cotton lint and cotton linter respectively over the study periods (Table 4). However, it was observed that the country had no revealed comparative advantage in the exportation of cotton waste, cotton carded and cotton seeds. The results showed positive and negative systematic pattern of changes for the RCA and RSCA respectively, across the years under consideration. However, when the average export's relative comparative advantage was considered for the overall period for each of the products, it was observed that the country only had revealed comparative advantage in the exportation of cotton linter while the remaining sub-sectors indicate negative advantage in the exportation of these products. Furthermore, the year-wise results for the cotton sector indicated that India had revealed comparative export advantage owing to growth trend in the export performance of the country in the global cotton trade markets.

India's share of global exports of cotton products indicate that RCA and RSCA changes are related to the changes of exports values. Consequently, India's share of global exports is such that whenever its' share of global exports inclines (or declines), the mentioned indices inclines (declines) as well. Thus, India can increase its revealed comparative advantage by subsidizing the prices of its products at international cotton market, thus enhancing its' world share export. But cautious need to be applied at the production level in order not to put the producers, value chain actors and the economy at disadvantage or peril.

The reason for India's revealed non-comparative advantage in the exportation of carded, cotton waste and seeds may be due to specialization in the production of lint and linter thereby affecting the supply quantities of cotton waste, carded and seeds whose share contribution to the cotton sector are minimal. Therefore, India needs to strengthen the sector to maximize sector benefit by devising a cost-cut mechanism in the production of their cotton products in order to enable them have a major breakthrough in the market and compete favorable with the cartel cotton giants whose production and quality stands are not better than that of India.

### 3.3. Export competitiveness (XCI) of India's cotton

Furthermore, year-wise empirical evidence showed that the country had export competitiveness in almost all the cotton products except cotton carded/combed which indicated relatively poor export competitive position in the global cotton market over the study period (Table 4). Investigating export competitiveness of India's cotton products illustrates the fact that India has the potential to achieve the comparative advantage in cotton exportation as evidenced by its advantages in the exportation of cotton lint and linter during the years under study. Furthermore, the year-wise results of the cotton sector indicated that the country had positive competitive export status over the study periods except for the years 2001, 2004, 2005, 2007 and 2008.

### 3.4. Relative trade advantage of India's cotton export

The results of the relative trade advantage (RTA) which reflects the real competitiveness and efficiency of trade of a country as it incorporates both exports and imports showed that India has positive trade advantage in the exportation of cotton linter and seeds throughout the study years. For cotton linter, the highest and lowest positive trade advantage years were 2001 and 2006 respectively, while for the cotton seeds, the highest and lowest positive trade advantage years were 2002 and year 2007 respectively. In addition, the country recorded positive RTA in the exportation of cotton as a whole across the study periods except from the year 2000 to 2005. However, the country recorded mostly negative RTA in the exportation of cotton lint, cotton waste and cotton carded/combed over the study period (Table 4). Therefore, it can be inferred that the country had a very negligible import advantage in cotton linter and cotton seeds indicating that it has been gaining competitiveness and the pace of growth was fast. However, the country had a very negligible export advantage in cotton lint, cotton waste and cotton carded, revealing poor competitiveness and pace of growth during the study period. The poor competitiveness and pace of growth in the India's cotton lint is associated to the price subsidies on lint offered by China and USA who are the major cotton exporting economies.

**Table 3: Growth and export value ('000 dollars) of India's cotton export**

| Years | Lint | | Linter | | Waste | | Carded | | Seeds | | Cotton | | World share % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Value | Growth | Value | Growth | Value | Growth | Value | Growth | Value | Growth | Value | Growth | |
| 2000 | 13725 | - | 3394 | - | 6074 | - | 30111 | - | 238 | - | 53542 | - | 0.74 |
| 2001 | 5942 | -56.70 | 1743 | -48.64 | 949 | -84.37 | 2616 | -91.31 | 117 | -50.84 | 11367 | -78.76 | 0.15 |
| 2002 | 9851 | 65.78 | 343 | -80.32 | 363 | -61.74 | 171 | -93.46 | 139 | 18.80 | 10867 | -4.39 | 0.16 |
| 2003 | 163047 | 1555.13 | 3573 | 941.69 | 2980 | 720.93 | 36394 | 21183.04 | 938 | 574.82 | 206932 | 1804.22 | 2.22 |
| 2004 | 69558 | -57.33 | 1641 | -54.07 | 6989 | 134.53 | 6430 | -82.33 | 213 | -77.29 | 84831 | -59.00 | 0.73 |
| 2005 | 639704 | 819.66 | 5294 | 222.60 | 8384 | 19.95 | 10700 | 66.40 | 192 | -9.85 | 664274 | 683.05 | 6.09 |
| 2006 | 1332636 | 108.32 | 4155 | -21.51 | 13702 | 63.43 | 2267 | -78.81 | 197 | 2.60 | 1352957 | 103.67 | 11.11 |
| 2007 | 2118257 | 58.952 | 10365 | 149.45 | 27372 | 99.76 | 2456 | 8.33 | 368 | 86.80 | 2158818 | 59.56 | 17.39 |
| 2008 | 642073 | -69.68 | 5294 | -48.92 | 19448 | -28.94 | 1352 | -44.95 | 4137 | 1024.18 | 672304 | -68.85 | 6.18 |
| 2009 | 1940656 | 202.24 | 27718 | 423.57 | 29601 | 52.20 | 1059 | -21.67 | 328 | -92.07 | 1999362 | 197.38 | 20.07 |
| 2010 | 2972199 | 53.15 | 46449 | 67.57 | 45373 | 53.28 | 953 | -10.00 | 1661 | 406.40 | 3066635 | 53.38 | 19.67 |
| 2011 | 3395689 | 14.24 | 36544 | -21.32 | 66736 | 47.08 | 679 | -28.75 | 2471 | 48.76 | 3502119 | 14.20 | 15.53 |
| 2012 | 3647834 | 7.42 | 35872 | -1.83 | 83276 | 24.78 | 602 | -11.34 | 826 | -66.57 | 3768410 | 7.60 | 17.33 |
| 2013 | 4533183 | 24.27 | 37041 | 3.25 | 121440 | 45.82 | 827 | 37.37 | 604 | -26.87 | 4693095 | 24.53 | 22.94 |
| Mean | | 194.67 | | 109.39 | | 77.62 | | 1488.03 | | 131.34 | | 195.47 | 10.02 |

**Table 4: Comparative advantage indices of India's cotton export during 2000-2013**

| Product | Index | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| Lint | RCA | 0.286312 | 0.579406 | 1.006738 | 0.860318 | 0.8929 | 1.044638 | 1.063299 | 1.065701 |
| | RSCA | -0.55483 | -0.2663 | 0.003358 | -0.07509 | -0.05658 | 0.021832 | 0.030679 | 0.031806 |
| | XCI | 1.125647 | 0.418273 | 1.832777 | 11.69038 | 0.344636 | 9.66468 | 1.857434 | 1.568095 |
| | RTA | -0.80559 | -0.51303 | -0.09686 | -0.22362 | -0.17123 | -0.00881 | 0.021866 | 0.011902 |
| Linter | RCA | 4.656025 | 10.39741 | 3.079759 | 1.989111 | 2.230456 | 1.024165 | 0.538999 | 0.668993 |
| | RSCA | 0.646395 | 0.824522 | 0.509775 | 0.330905 | 0.380892 | 0.011938 | -0.29955 | -0.19833 |
| | XCI | 5.372596 | 0.461557 | 0.312441 | 8.835444 | 0.37235 | 3.793158 | 0.960378 | 1.941895 |
| | RTA | 4.656025 | 10.39741 | 3.079759 | 1.989111 | 2.230456 | 1.024165 | 0.538999 | 0.668993 |
| Waste | RCA | 3.237256 | 2.478601 | 0.928644 | 0.449394 | 2.554307 | 0.440027 | 0.351818 | 0.405793 |
| | RSCA | 0.527996 | 0.425056 | -0.037 | -0.37989 | 0.437302 | -0.38886 | -0.47949 | -0.42268 |
| | XCI | 0.994808 | 0.15825 | 0.395202 | 6.620094 | 1.887395 | 1.423085 | 1.459025 | 1.804591 |
| | RTA | 3.081927 | 2.32689 | 0.792005 | 0.134945 | 2.075608 | -0.35725 | -0.66977 | -0.17551 |
| **Product** | **Index** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** | **Mean** | |
| Lint | RCA | 1.058887 | 1.074739 | 1.059059 | 1.04866 | 1.06441 | 1.067069 | 0.940867 | |
| | RSCA | 0.028601 | 0.036023 | 0.028683 | 0.023752 | 0.0312 | 0.032446 | -0.04889 | |
| | XCI | 0.353298 | 3.293639 | 0.965836 | 0.781955 | 1.132802 | 1.326607 | 2.596861 | |
| | RTA | -0.009 | -0.00865 | 0.022205 | -0.00748 | -0.00324 | -0.00428 | | |
| Linter | RCA | 0.828692 | 0.83725 | 0.644613 | 0.836847 | 1.28873 | 1.153351 | 2.155315 | |
| | RSCA | -0.09368 | -0.08858 | -0.21609 | -0.08882 | 0.126153 | 0.071215 | 0.13691 | |
| | XCI | 0.440452 | 3.278571 | 0.754623 | 1.025213 | 1.718682 | 1.184291 | 2.175118 | |
| | RTA | 0.828692 | 0.83725 | 0.644613 | 0.836847 | 1.287341 | 1.148093 | | |
| Waste | RCA | 0.790301 | 0.439459 | 0.523573 | 0.615822 | 0.798045 | 0.797686 | 1.057909 | |
| | RSCA | -0.11713 | -0.38941 | -0.3127 | -0.23776 | -0.11232 | -0.11254 | -0.11425 | |
| | XCI | 0.692492 | 1.804467 | 1.167736 | 0.928849 | 1.446279 | 1.322706 | 1.578927 | |
| | RTA | 0.428956 | -0.06 | -0.67443 | 0.078358 | 0.690235 | 0.662034 | | |

**Table 4: Continued**

| Product | Index | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| Carded | RCA | 21.54274 | 11.14746 | 0.802643 | 7.918625 | 4.628862 | 0.81183 | 0.090952 | 0.055796 |
| | RSCA | 0.91128 | 0.835356 | -0.10948 | 0.77575 | 0.644688 | -0.10386 | -0.83326 | -0.89431 |
| | XCI | 129.01 | 0.106952 | 0.075949 | 134.9626 | 0.194107 | 1.448823 | 0.204442 | 0.959806 |
| | RTA | 21.45193 | 11.07546 | 0.742581 | 7.848239 | 4.46644 | 0.649618 | -0.04335 | -0.45362 |
| Seeds | RCA | 0.148582 | 0.358358 | 0.379136 | 0.213712 | 0.10296 | 0.013239 | 0.007017 | 0.008328 |
| | RSCA | -0.74128 | -0.47237 | -0.45018 | -0.64784 | -0.8133 | -0.97387 | -0.98606 | -0.98348 |
| | XCI | 1.933842 | 0.498501 | 1.115975 | 7.711152 | 0.159977 | 1.062241 | 0.967218 | 1.856754 |
| | RTA | 0.148582 | 0.358358 | 0.379136 | 0.211537 | 0.10296 | 0.013239 | 0.007017 | 0.004934 |
| Cotton | RCA | 1.105307 | 0.211584 | 0.202677 | 2.719784 | 0.857792 | 6.175849 | 10.76262 | 15.67456 |
| | RSCA | 0.05002 | -0.65073 | -0.66296 | 0.462334 | -0.07655 | 0.721287 | 0.82997 | 0.880057 |
| | XCI | 2.502323 | 0.23432 | 1.062162 | 11.66365 | 0.336646 | 8.094558 | 1.822042 | 1.563696 |
| | RTA | -3.67823 | -7.50196 | -4.57892 | -2.11431 | -1.57982 | 4.719151 | 9.669713 | 14.10847 |

| Product | Index | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Mean |
|---|---|---|---|---|---|---|---|---|
| Carded | RCA | 0.081872 | 0.02181 | 0.018831 | 0.013438 | 0.004564 | 0.00516 | 3.36747 |
| | RSCA | -0.84865 | -0.95731 | -0.96304 | -0.97348 | -0.99091 | -0.98973 | -0.32121 |
| | XCI | 0.521748 | 0.864457 | 0.846234 | 0.563572 | 0.379078 | 1.495942 | 19.40241 |
| | RTA | -0.30005 | -0.10058 | -0.29029 | -0.18481 | -0.08804 | -0.11266 | |
| Seeds | RCA | 0.224501 | 0.007347 | 0.032661 | 0.040223 | 0.010694 | 0.006027 | 0.110913 |
| | RSCA | -0.63332 | -0.98541 | -0.93674 | -0.92266 | -0.97884 | -0.98802 | -0.82238 |
| | XCI | 9.585497 | 0.1062 | 4.35704 | 0.972572 | 0.296705 | 0.74586 | 2.240681 |
| | RTA | 0.224501 | 0.007347 | 0.032661 | 0.038674 | 0.010694 | 0.005227 | |
| Cotton | RCA | 4.961365 | 14.75401 | 12.83616 | 9.127244 | 10.60585 | 13.64697 | 7.402984 |
| | RSCA | 0.664506 | 0.873048 | 0.855451 | 0.802513 | 0.827673 | 0.863453 | 0.460006 |
| | XCI | 0.356302 | 3.238645 | 0.979794 | 0.789645 | 1.115995 | 1.323163 | 2.505925 |
| | RTA | 2.606327 | 12.79791 | 12.49079 | 8.69917 | 9.403886 | 12.52107 | |

### 3.5. Trade mapping index

A perusal of Table 5 showed the Trade Mapping and competition situation of India's cotton sector in the global markets. The exogenous factor that may cause reduction or loss of the comparative advantage of exports includes price subsidies offered by other major exporting countries and increase in the production of other countries. In addition, trade agreements of other countries with the recipient countries for reducing trade barriers thereby increasing the export share, and the problems due to the entry of these goods in the importing countries.

Trade mapping analysis for export markets of India's cotton sector indicates a threshold in the export market of cotton products during the studied period, having low market share and the country is among the winner groups. Furthermore, the decomposition analysis of the Trade mapping analysis for the cotton products showed that the export markets for cotton linter and carded declined during the studied period with the market shares been poor. The export market of India's cotton seeds was at a threshold between decline and increase; and has low market share. However, the export markets of cotton lint and waste declined during the studied period with low market shares. Furthermore, it was observed that India is among the winner groups for cotton lint, cotton waste and cotton linter; and among the loser groups for cotton carded and seeds.

**Table 5: Trade mapping index (TMI) for India's cotton export**

| Product | Growth % | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| Lint | WIG | - | 2.71546 | -9.36676 | 39.19762 | 23.45542 | -5.20877 | 11.61254 | 1.985812 |
| | WCIG | - | 3.504915 | -9.54385 | 41.58064 | 23.78664 | -4.84218 | 12.1551 | 1.366558 |
| | ICEG | - | -56.7067 | 65.78593 | 1555.131 | -57.3387 | 819.6699 | 108.3207 | 58.95241 |
| | Assessment | - | LEM | WDM | WEM | LEM | WEM | WEM | WDM |
| Linter | WIG | | 2.71546 | -9.36676 | 39.19762 | 23.45542 | -5.20877 | 11.61254 | 1.985812 |
| | WCIG | | 11.26539 | -37.0162 | 17.89911 | 23.34574 | -14.95 | -18.2769 | 28.46139 |
| | ICEG | | -48.6447 | -80.3213 | 941.691 | -54.0722 | 222.6082 | -21.5149 | 149.4585 |
| | Assessment | | LEM | LDM | WDM | LDM | WDM | LDM | WEM |
| Waste | WIG | - | 2.71546 | -9.36676 | 39.19762 | 23.45542 | -5.20877 | 11.61254 | 1.985812 |
| | WCIG | - | -1.27061 | -3.21198 | 24.0068 | 24.26129 | -15.7043 | 12.01343 | 10.69901 |
| | ICEG | - | -84.376 | -61.7492 | 720.9366 | 134.5302 | 19.95994 | 63.43034 | 99.76646 |
| | Assessment | - | LDM | LEM | WDM | WEM | WDM | WEM | WEM |

| Product | Growth % | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Mean |
|---|---|---|---|---|---|---|---|---|
| Lint | WIG | -12.4165 | -8.35615 | 56.48923 | 44.61105 | -3.58437 | -5.88856 | 9.660432 |
| | WCIG | -14.2045 | -8.23266 | 58.57177 | 46.10608 | -5.1684 | -6.32455 | 9.911114 |
| | ICEG | -69.6886 | 202.2485 | 53.15435 | 14.24837 | 7.425444 | 24.27054 | 194.6767 |
| | Assessment | LDM | WEM | LEM | LEM | WDM | WDM | |
| Linter | WIG | -12.4165 | -8.35615 | 56.48923 | 44.61105 | -3.58437 | -5.88856 | 9.660432 |
| | WCIG | 15.96209 | 59.69577 | 122.0671 | -23.2593 | -42.8858 | -12.8096 | 9.249914 |
| | ICEG | -48.9243 | 423.5739 | 67.57703 | -21.3245 | -1.83888 | 3.258809 | 109.3948 |
| | Assessment | LEM | WEM | LEM | WDM | WDM | WDM | |
| Waste | WIG | -12.4165 | -8.35615 | 56.48923 | 44.61105 | -3.58437 | -5.88856 | 9.660432 |
| | WCIG | 2.601479 | -15.6505 | 31.26419 | 58.34979 | -13.7205 | 10.24999 | 8.849151 |
| | ICEG | -28.9493 | 52.20588 | 53.28198 | 47.08307 | 24.78422 | 45.82833 | 77.62375 |
| | Assessment | LEM | WDM | WDM | LEM | WDM | WEM | |

**Table 5: Continued**

| Product | Growth % | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|
| Carded | WIG | - | 2.71546 | -9.36676 | 39.19762 | 23.45542 | -5.20877 | 11.61254 | 1.985812 |
| | WCIG | - | -18.7689 | -13.9333 | 57.69585 | -8.97935 | 14.85698 | 3.632766 | 12.87388 |
| | ICEG | - | -91.3121 | -93.4633 | 21183.04 | -82.3323 | 66.40747 | -78.8131 | 8.337009 |
| | Assessment | - | LDM | LDM | WEM | LDM | WEM | LDM | LEM |
| Seeds | WIG | - | 2.71546 | -9.36676 | 39.19762 | 23.45542 | -5.20877 | 11.61254 | 1.985812 |
| | WCIG | - | -1.38511 | 6.457043 | -12.4878 | 41.94481 | -15.1409 | 6.081754 | 0.606776 |
| | ICEG | - | -50.8403 | 18.80342 | 574.8201 | -77.2921 | -9.85915 | 2.604167 | 86.80203 |
| | Assessment | - | LDM | WEM | WDM | LEM | WDM | LDM | WDM |
| Cotton | WIG | - | -3.86021 | 3.073955 | 16.36188 | 22.06839 | 14.09384 | 14.99651 | 15.28594 |
| | WCIG | - | 2.71546 | -9.36676 | 39.19762 | 23.45542 | -5.20877 | 11.61254 | 1.985812 |
| | ICEG | - | -78.7699 | -4.3987 | 1804.224 | -59.0054 | 683.0557 | 103.6745 | 59.56294 |
| | Assessment | - | LEM | WDM | WEM | LEM | WDM | WDM | WDM |
| Product | Growth % | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Mean | |
| Carded | WIG | -12.4165 | -8.35615 | 56.48923 | 44.61105 | -3.58437 | -5.88856 | 9.660432 | |
| | WCIG | 5.508525 | -9.39003 | 6.342395 | 26.42339 | 133.8828 | -8.16794 | 14.42694 | |
| | ICEG | -44.9511 | -21.6716 | -10.0094 | -28.7513 | -11.3402 | 37.37542 | 1488.037 | |
| | Assessment | LEM | LDM | LDM | LDM | LEM | WDM | | |
| Seeds | WIG | -12.4165 | -8.35615 | 56.48923 | 44.61105 | -3.58437 | -5.88856 | 9.660432 | |
| | WCIG | 17.27976 | -25.3442 | 16.22625 | 52.9612 | 12.66332 | -1.96088 | 6.993011 | |
| | ICEG | 1024.185 | -92.0715 | 406.4024 | 48.7658 | -66.5722 | -26.8765 | 131.3479 | |
| | Assessment | WEM | LDM | WDM | LEM | LEM | LEM | | |
| Cotton | WIG | 15.47251 | -22.9719 | 21.66803 | 19.85707 | 0.694165 | 1.662099 | 8.457306 | |
| | WCIG | -12.4165 | -8.35615 | 56.48923 | 44.61105 | -3.58437 | -5.88856 | 9.660432 | |
| | ICEG | -68.8578 | 197.3896 | 53.38068 | 14.20071 | 7.603711 | 24.5378 | 195.4713 | |
| | Assessment | LDM | WEM | LEM | LEM | WDM | WDM | | |

Note: WIG (World import growth %); WCIG (World cotton import growth %); ICEG (India's cotton export growth %)

### 3.6. Prioritization of export target's market for India's cotton

To introduce the best potential target markets the major India's cotton importing economies were identified and based on the market potential indicator the countries were prioritized. The results of the market attractiveness indicators placed only two countries namely China and Malaysia out of the seven importing countries as the potential export markets for India's cotton (Table 6). Thus, with regard to prioritization in the exportation of cotton, India should endeavor to adopt some important policies.

**Table 6: Prioritization of potential target export markets for India's cotton**

| Country | PC |
|---|---|
| China | 0.605123 |
| Bangladesh | -0.04965 |
| Indonesia | -0.06383 |
| Malaysia | 0.013209 |
| Thailand | -0.18588 |
| Turkey | -0.06112 |
| Korea Rep. | -0.12763 |

Note: PC- Prioritization coefficient

### 3.7. Market structure of India's cotton export

The year-wise cursory review of the results showed that the market structure of India's cotton export in the year 2000 and 2001 was characterized by closed oligopoly, and beyond these periods the exportation market was characterized by monopoly structure (Table 7). This indicates that government of India was the only channel of exportation of cotton to the global market. This outcome is not surprise as government intervention is very essential to protect India's cotton producers from the imperfect market situation that prevails in the cotton global market due to bear raid in the market by China and USA. However, government of India should devise a marketing means of being efficient in the global trade market as this intervention is likely not to be sustainable in the long-run. Furthermore, it was observed that the sector was highly diversified in the first two years, suddenly plummeted to very low diversification in the year 2002and the slightly rise to low diversification across the year 2003 to 2004. Thereafter, it plummeted to very low diversification receding towards specialization across the remaining periods.

**Table 7: Export trade structure of India's cotton**

| Year | Market structure | 1/HHI | BID | EID | DBID | DEID |
|---|---|---|---|---|---|---|
| 2000 | Monopolistic competition | 2.506954 | 0.60111 | 0.159216 | 75.1387 | 22.77861 |
| 2001 | Monopolistic competition | 2.802599 | 0.643188 | 0.159695 | 80.39855 | 22.84718 |
| 2002 | Monopolistic competition | 1.213185 | 0.175724 | 0.069179 | 21.96546 | 9.897304 |
| 2003 | Monopolistic competition | 1.533074 | 0.347716 | 0.12104 | 43.46445 | 17.31689 |
| 2004 | Monopolistic competition | 1.459327 | 0.314753 | 0.112485 | 39.34408 | 16.09299 |
| 2005 | Monopolistic competition | 1.077731 | 0.072125 | 0.030166 | 9.015631 | 4.315739 |
| 2006 | Monopolistic competition | 1.030608 | 0.029699 | 0.012705 | 3.712371 | 1.817624 |
| 2007 | Monopolistic competition | 1.038464 | 0.037039 | 0.015784 | 4.629862 | 2.2582 |
| 2008 | Monopolistic competition | 1.095254 | 0.08697 | 0.036078 | 10.87123 | 5.161635 |
| 2009 | Monopolistic competition | 1.060953 | 0.057451 | 0.02422 | 7.181361 | 3.465063 |
| 2010 | Monopolistic competition | 1.064047 | 0.060192 | 0.025338 | 7.524037 | 3.625071 |
| 2011 | Monopolistic competition | 1.063133 | 0.059384 | 0.025009 | 7.423029 | 3.577958 |
| 2012 | Monopolistic competition | 1.066542 | 0.06239 | 0.026232 | 7.798779 | 3.752998 |
| 2013 | Monopolistic competition | 1.070956 | 0.066255 | 0.027799 | 8.281853 | 3.977154 |

Source: Authors' computation, 2018

## 4. Conclusion and Recommendation

The present research empirically examined the export competitiveness of India's cotton products in the global cotton trade markets. The empirical evidence revealed that India's cotton products with the exception of cotton lint did not have revealed export comparative advantage in the international cotton markets during the study period. However, based on the trade mapping analysis the export of cotton lint, the major export earning of India emerged in the global trade market during the study period despite having small share and the country is found to be among the winner group. Furthermore, for the cotton sector as a whole, the export market has been at a threshold with the country share been small, and it is among the winner groups.

Hence, in order for India to have a comparative advantage for cotton in the export market and its continuing presence in the world markets, the following recommendations are suggested:

- Special attention towards increasing productivity and minimizing costs *via* improved varieties, proper mechanization, enhanced quality and production methods should be considered as appropriate actions or solutions to improve the position of exporting products amongst commercial competitors.
- The commercial production status and behavior of the competing countries especially China and USA need to be fully monitored by manufacturers, exporters, and domestic decision makers to deal with the effects of externalities. Furthermore, timely and appropriate responses should be done to improve the competitive position of these products in the target importing markets.
- Since not all the countries qualify as target importing market, effort should be made to penetrate these markets by accurate systematic plan coupled with increasing competition and competitiveness. For this purpose, the exporter of various cotton products should select the proper number of the priority markets and infiltrate them by awareness of the competitors, rules and regulations of marketing, and by having a coherent marketing plan.

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# Prediction of Maximum Sustainable Yield and Optimum Fishing Effort for the Nile Perch (*Lates niloticus* L.) in Lake Chamo, Ethiopia

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Received: October 10, 2019 Accepted: February 16, 2020

**Abstract:** *The study was conducted to assess the current status and determine the maximum sustainable yield level of exploitation for the Nile perch (Lates niloticus L., 1758) a stock in Lake Chamo, Ethiopia. Data were collected from eight major landing sites of Lake Chamo for three days in a week for ten months (February to November, 2018). The total length, sample weight and total weight of L. niloticus caught by the fishers and the fishing efforts were the basic information collected from these sites. Totally, 544 L. niloticus samples were collected in 120 days. Jones length based cohort analysis model and length-based Thompson and Bell yield prediction models were employed to estimate the maximum sustainable yield. Overall about 0.25 million L. niloticus populations were estimated to exist in the lake. The estimated current annual yield was 102.4 tons per year. However, the predicted value of MSY was 74 tons obtained at* $f_{MSY}$ *of 9,007 nets. The maturity length* ($L_{50}$) *was 100 cm and out of the total annual catches 87.9% of L. niloticus were below their respective size of maturity. Thus, the reduction of yield was due to experiencing both growth and recruitment overfishing with increased effort and reduced mesh size. Lates niloticus of Lake Chamo is overfished. Therefore, conservation and rehabilitation as well as co-management practices are required for sustainable utilization of the resource.*

**Keywords:** Jones length based cohort analysis model, Lake Chamo, stock assessment, yield prediction



## 1. Introduction

In Ethiopia, water bodies have an estimated surface area of 7,334 km² of major lakes and reservoirs, and 275 km² of small water bodies, with 7,185 km of rivers (FAO, 2003).The Ethiopian Rift Valley Lakes belong to a group of lakes formed by the East African Rift, running from north to south on the eastern side of the African continent. Most lakes are highly productive and well known for their aquatic diversity and indigenous populations of edible fish species (Tudorancea and Taylor, 2002; Ayenew and Legesse, 2007).

Lake Chamo is one of the Rift Valley Lakes in Ethiopia and due to the combined effect of an increasing number of fishing nets and vessels; the Nile perch (*Lates niloticus*) stock is clearly being over-exploited as seen from the overall catch composition from the lake (Ward and Wakayo, 2013; Mulugeta and Mereke, 2016).

*L. niloticus* is widely accepted fish species as a food commodity and are economically important for the fishing societies in Lake Chamo. Nowadays, *L. nilotcus* is the most target fish species of Lake Chamo fisheries due to its high price value in the market. To get high income, irresponsible fishing practices are taking place that may cause depletion of the resource. To save the resources from depletion, determining the optimum level of exploitation is important and the primary goal of this study was searching for the optimum level of exploitation. The finding of this study would serve as an essential input for decision-makers in recommending proper fish resource utilization and management.

## 2. Materials and Methods

### 2.1. Description of the study areas

Lake Chamo is geographically located at 5°42′–5°58′ N Latitude and 37°27′– 37°38′ E Longitude and it is one of Ethiopian Rift Valley lakes with an area of 551 km$^2$ and a maximum depth of 16 m (Belay and Wood, 1982). The lake is located at an altitude of 1108 m and about 515 km south of the capital city Addis Ababa (Dadebo *et al.*, 2005).

Lake Chamo is part of the Ethiopian Rift Valley Lakes Basin (ERVLB) in the Abaya–Chamo drainage sub-basin (ACB). The ERVLB comprises eight natural lakes and their tributaries. The ACB comprises Lake Chamo and Lake Abaya, and rivers and streams entering the lakes. The two lakes are connected via surface hydrology. Outflow from Lake Abaya enter Lake Chamo through River Kulfo, and an overflow from Lake Chamo through Metenafesha joins Sermale River in Amaro Woreda (Bekele, 2006). Earlier studies stated that, Lake Chamo has a surface area of 551 $km^2$ and a maximum depth of 16m (Belay and Wood, 1982). However, according to Bekele (2006), the surface area of the lake declined to about 335 $km^2$. The high rate of evaporation of water and the diversion of the feeder river, Kulfo, for agricultural activities are the reasons for the decline in the surface area of the lake (Kebede, 1996).

The fishery on Lake Chamo is almost exclusively conducted with a surface gillnet, although long–lines are also used to some extent to African catfish (*Clarias gariepinus)* and *Bagrus docmak.* The nets are prepared locally by fishers themselves or by some other people involved in fishing gear making activity. The gill nets are the most important fishing gears and are typically set in the afternoon and hauled early in the morning. They are removed only to change the fishing ground or when maintenance is necessary.

## 2.2. Methods of sampling and data collection

In Lake Chamo, there are five legal fishers' co-operatives who are landing their fish catches on 31 major landing sites (from fishers' co-operatives). Of these, eight major landing sites (Bole, Ashewa, Gentafora, Bedena 1, Chika, Mehal, Wedeb and Girawa) were selected randomly and used as sampling sites. Due to differences in the number of nets deployed in 31 landing sites, the estimated total annual catch from 31 landing sites were obtained by multiplying the annual estimated catch from 8 landing sites by the fraction of **(**total estimated nets from 31 landing sites**)/(**total estimated nets from 8 sample landing**)** sites with the catch of respective length groups.

Sixteen data collectors; two from each landing sites were trained to collect data from the commercial fish catches. The catch data were collected for ten months (February to November 2018). Data were collected from randomly selected boats in randomly selected 3 days in a week. During each day of sampling, the total lengths (TL) of randomly selected samples of *L. niloticus* was measured to the nearest 1 mm by using a measuring board, sample weights and total weights of fish from each boat was measured to the nearest 1 g and 100 g, respectively by using electronic and hanging scale balances. In addition sample nets and total number of nets deployed into the lake per day were recorded.

## 2.3. Data summarization and analysis

The catch statistics data was summarized in a manner useful for Jones length-based cohort analysis and length-based Thompson and Bell yield prediction model. The summarization and analysis were done by using Microsoft Office Excel (2010) software.

### 2.3.1. *Arrangement of length composition data*

The length composition of catch data were summarized as a table of the average total annual catch distributed by length groups. This was done as follows:

I. Length measurements recorded were grouped into 7cm length intervals to prepare a table of the length frequency. The interval was 7 cm because it was the least interval between the consecutive length groups in the sample.
II. Estimating the total number of fish caught during un-sampled days of the year was done by multiplying the average catch per day of the sampled 120 days of catch by the number of un-sampled days during the year.

***Estimating the annual total length composition of fish landed***

This was done by raising the length frequency of the sampled 120 days of catch by an appropriate raising factor which is equal to C/c, in which 'C'- the estimated total catch of fish during the whole twelve months and 'c'- the total catch of fish during the 120 days of sampling.

### 2.3.2. *Estimating mortality parameters based on length composition data*

For the estimation of total mortality rates, linearized length converted catch curve method was applied. Required input data was length-structured catch data randomly sampled from the commercial fishery and the relative age of the fish that corresponds to the mid length of the size groups, which was calculated by the following formula:

$\Delta t = 1/k * Ln[(L\infty - L_1)/[(L\infty - L_2)]$ [1]
$t (L_1+L_2)/2 = -1/k\{Ln[(1-(L_1+L_2)/2/(L\infty)]$ [2]
$Ln\{[C(L_1,L_2)]/[\Delta t(L_1,L_2)]\} = a - Z*t(L_1+L_2)/2$ [3]

Where:

$\Delta t$ = is age interval between $L_1$ and $L_2$ or the time taken by $L_1$ to reach $L_2$
$t (L_1+L_2)/2$ = age of the average consecutive length groups (X variable)
$Ln\{[C(L_1,L_2)]/[\Delta t(L_1,L_2)]\}$ = Y variable

To obtain total mortality, regression analysis was conducted between X and Y variables.

Total mortality (Z) = fishing mortality (F) + natural mortality (M) [4]

The natural mortality coefficient (M) was estimated using Pauly's (1980) empirical formula as follows:
$Log_{10} M = - 0.0066 - 0.279Log_{10}L_\infty + 0.65443Log_{10} K + 0.4634Log_{10}T$ [5]

Where,

M = is natural mortality coefficient
$L\infty$ = asymptotic length
K = growth constant
T = mean annual surface water temperature of the lake

Then, the fishing mortality rate (F) was calculated by subtracting M from Z.

**2.3.3.** ***Estimating population sizes and fishing mortalities by length group (Jones, 1984)***

Jones length-based cohort analysis model was used to estimate the population size and fishing mortality coefficient of *L. niloticus* by length groups. This was done in three steps as follows:

i). Estimating the population number of the largest length group in the catch

This was done as follows:

N(largest L) = C(Largest L)*(Z Largest L/F Largest L ) [6]

Where,
N(largest L) = the population of the largest length group in the catch
C(largest L) = the catch of the largest length group
Z(largest L) = the total mortality rate of the largest length group in the catch
F(largest L) = the fishing mortality rate of the largest length group in the catch
$C(L_1,L_2)$ = the catch of the length groups of $N(L_1)$

ii). Estimating the population numbers of consecutively younger length groups in the catch

This was done using the equation as follows:

$N(L_1) = [N(L_2) * H(L_1,L_2) + C(L_1,L_2)] * H(L_1,L_2)$ [7]

Where,
$N(L_1)$ = The population number of $L_1$ (younger) fish
$N(L_2)$ = The population number of $L_2$(older) fish
$H(L_1,L_2)$ = the fraction of $N(L_1)$ fish that survived natural death as it grows from length $L_1$ to $L_2$ and computed as the following equation (Jones, 1984).

$H(L_1,L_2) = [(L\infty - L_1)/ (L\infty - L_2)]^{(M/2K)}$ [8]

Where,

$L\infty$= the asymptotic length (cm) of *L. niloticus* attained at mature size
$L_1$ and $L_2$= consecutive length groups of fish (cm) that contributed to the fishery
K = von Bertalanffy growth rate constant ($yr^{-1}$)
M = the rate of natural mortality coefficient for *L. niloticus* stock of Lake Chamo

iii). Estimating the fishing mortality rate of the respective length groups

Fishing mortality values for each length group was estimated using the equation as follows:

$F(L_1,L_2) = (1/\Delta t) * ln[N(L_1)/N(L_2)] – M$ [9]

Where,

$F(L_1,L_2)$ = Fishing mortality coefficient pertaining to the respective length group
$N(L_1)$, $N(L_2)$ and M are as defined above

To know the status of the stock, the exploitation rate (E) was estimated from mortality parameters as: E = F/Z. The exploitation rate (E) equal to 0.5 is considered as optimum level of exploitation; whereas less than 0.5 refers to under exploitation and greater than, 0.5 refers to overexploitation (Gulland, 1971).

2.3.4. ***Predicting maximum sustainable yield and optimum fishing efforts***

Input data and parameters required were:

i) Total number of fish caught per year structured by length groups
ii) Estimates of population number and fishing mortality coefficient (F) by length group (obtained from Jones length based cohort analysis)
iii) Values of the von Bertalanffy growth parameters (L∞ and K) and natural mortality coefficient (M)
iv) Mean weight of fish for each length group obtained as described above for cohort analysis

***Thompson and Bell (1934) yield prediction procedure***

Step 1) Estimating the total annual yield obtained under the current level of fishing

i) Estimating the yield obtained per year from each length group
   - Yield from each length group obtained per year ($Y(L_1,L_2)$ - was catch in number per length group per year ($C(L_1,L_2)$ multiplied by the average weight of each length group i.e.,

$$Y(L_1, L_2) = C(L_1, L_2) * W(L_1, L_2) \quad [10]$$

Where,

$Y(L_1, L_2)$ = the yield (weight) of fish obtained per year from respective length group

$C(L_1, L_2)$ = total annual catch of fish obtained from respective length group

$W(L_1, L_2)$ = the mean weight of each length group estimated using equation

$$W(g) = a * L^b \quad [11]$$

Where,

W(g) is the average weight of each length group,

L = the average length (cm) of each length group i.e.,

$L = (L_1+L_2)/2$ in which $L_1$ and $L_2$ are the length intervals of consecutive length groups. '*a*' and '*b*' are values of the regression coefficients

ii) Estimating yield obtained from all length groups per year

Adding up the contribution of each length group gives the total yield obtained from the stock per year.

Step 2) predicting yield obtained under different levels of fishing pressure

- If the fishing pressure exerted on the stock changes, obviously the yield also changes (increases or decreases)
- Hence the yield obtained under different levels of fishing pressure was predicted by changing the current level of fishing pressure by a certain factor
- In due regard the fishing level that gives the maximum yield is assumed to be optimum fishing level and is recommend to the management for sustainable fishing

Step 3) Yield prediction under doubling of the fishing effort

- Doubling the fishing effort also doubles the fishing mortality rate
- Fishing mortality and fishing effort are related as follows

$$F = q*f \quad [12]$$

Where,

F= fishing mortality,

q = catchability coefficient and f= fishing effort

***Procedures of predicting yield under the doubled F:***

i) Calculating the changed fishing mortality
   - The new fishing mortality values under the changed F was calculated by multiplying the current F by the raising factor (X)

$$F(New) = F(current)* X, \quad [13]$$

Where,

F(new) = the changed F

ii) Calculating the changed total mortality rate under the changed F

$$Z(new) = F(new) +M \quad [14]$$

Where,

F(new) is the changed fishing mortality coefficient of each length group. M is the natural mortality coefficient estimated by equation 5 above.

iii) Predicting the population number of fish under the changed fishing mortality

Since a change in fishing mortality obviously results in a change in population number of fish in the water, new estimates of population numbers in each length group need to be predicted under the changed fishing mortality condition. Thus, the population numbers under the changed fishing mortality were calculated from the following exponential decay relationship (Schnute, 1987; Sparre and Venema, 1992).

$$N(L_2) = N(L_1) * e^{-Z(new)*\Delta t(L1,L2)} \quad [15]$$

Where,

$N(L_1)$ is the population number of length $L_1$ fish
$N(L_2)$ is the population number of length $L_2$ fish
$\Delta t$ $(L_1, L_2)$ is the time it takes for an average fish to grow from length $L_1$ to length $L_2$ and it is defined earlier by equation 1.
Z(new) is the total mortality under the changed level of fishing and it is equal to the sum of the changed fishing mortality as defined above by equation 14.

iv) Estimating the total death and catch in each length group under the changed fishing level

The total number of deaths expected while the fish grew from length $L_1$ to length $L_2$, i.e., $D(L_1, L_2)$ under the changed fishing level is equal to $N(L_1) – N(L_2)$. From this total death, the fraction died due to fishing make up the total catch. Accordingly, the catch per length interval corresponding to the changed fishing mortality$[C(L_1, L_2)]$ was calculated from the following relationship (Wetherall *et al.*, 1987).

$$C(L_1, L_2) = F(L_1,L_2)/Z(L_1,L_2) * D(L_1,L_2) \quad [16]$$

Where,

$F(L_1,L_2)$ and $Z$ $(L_1,L_2)$ are the fishing and total mortality coefficients, respectively, under the changed level of fishing effort.

Then, to estimate the expected yield obtained from respective length groups annually $(Y(L_1,L_2))$ under the changed fishing mortality, the expected catch in number under the changed fishing level was multiplied by the mean weight of each length group as illustrated by equation 10. The total annual yield to be expected under the new level of fishing effort was then predicted by summing up the contributions of each length group.

Such predictions were evaluated for different values of fishing mortalities so as to see the full spectrum of the effect of changing fishing effort on the stock. According to the above analysis, the level of fishing mortality that gave maximum sustainable yield was considered as the biologically optimum level of fishing mortality. Since there is a one to one correspondence between fishing mortality (F) and fishing effort (f), the value of F-factor chosen as optimum was used to recommend how much the current level of fishing effort need to be increased or decreased to get the maximum sustainable yield from the stock (Sparre and Venema, 1992).

## 3. Results and Discussion

### 3.1. Status of Lake Chamo *L. niloticus* fishery

Overall there were five fishers' co-operatives and 300 registered co-operative member of fishermen operating in the lake during the time of sampling (Table 1). The fishing nets of Lake Chamo fishers are constructed differently considering the size of the target fish and set differently. These fishers own 60 boats and on average 49 nets for *L. niloticus,* which were set daily in the lake. Each fisher on average owns 0.16 *L. niloticus* nets and about 0.82 nets were set per boat daily. The total annual estimated nets were 17,885 during the year of investigation (365 days). With this level of fishing efforts, an estimated total annual catch were 15,868 and weighed about 102.4 tons per year. The estimated average catch per net per day was 1 fish and weighed 5.73 kg/net/day.

**Table 1: Catch statistics of *L. niloticus* fishery of Lake Chamo in 2018**

| Operation measurements | Value |
|---|---|
| Total number of fishers in operation | 300 |
| Average number of boat operated per day | 60 |
| Average nets set per day | 49 |
| Total number of nets set per year | 17,885 |
| Total number of fish caught per year | 15,868 |
| Total weight of catch (kg) per year | 102,400 |
| Catch per net (no./net/day) | 1.0 |
| Weight of catch per net (kg/net/day) | 5.73 |

### 3.2. The length composition of sampled catch and estimated annual catch of *L. niloticus*

Totally, 544 samples of *L. niloticus* were measured during the study period and the measured total length (TL) compositions were ranged from 35 to 126 cm with an average length of 80.5 cm (Table 2). From 544 fish measured, only 66 were greater than the maturity length ($L_{50}$) of 100 cm which was reported by Dadebo *et al*. (2005). Thus, 12.1% of the fish caught were above $L_{50}$ and the remaining 87.9% were below $L_{50}$.

A similar result was reported by Dejene (2008), who estimated the proportion of immature *L. niloticus* as 94.3%. As observed during the data collection, the mesh sizes of nets used to catch the fish were found to be 20 cm which was narrower than the recommended minimum mesh size as 28 cm (LFDP, 1997).Out of the total annual catch, over 95.61% of the catch was ranged from 42 cm to 112 cm in total length. More importantly, the length groups ranged from 49 cm to105 cm was about 88.76% of the total catch and had a high contribution in fish yield Table 2 (column 4, rows 5-12). Thus, large numbers of *L. niloticus* of Lake Chamo are being removed before they grow and replace their population.

**Table 2: Nile perch caught during the sampled days and estimated total annual catch by length group in 2018**

| Length group **L1-L2** | Samples/120 days C ($L_1$,$L_2$) | Estimated annual catch (number) | Proportion of length group composition from the total catch (%) |
|---|---|---|---|
| 35-42 | 7 | 204 | 1.3 |
| 42-49 | 17 | 496 | 3.13 |
| 49-56 | 37 | 1079 | 6.79 |
| 56-63 | 67 | 1954 | 12.32 |
| 63-70 | 80 | 2334 | 14.70 |
| 70-77 | 82 | 2392 | 15.07 |
| 77-84 | 73 | 2129 | 13.43 |
| 84-91 | 64 | 1867 | 11.77 |
| 91-98 | 51 | 1488 | 9.38 |
| 98-105 | 29 | 846 | 5.34 |
| 105-112 | 20 | 583 | 3.68 |
| 112-119 | 11 | 321 | 2.02 |
| 119-126 | 6 | 175 | 1.11 |
| Total | 544 | 15,868 | 100 |

### 3.3. Growth and total mortality coefficient of *L. niloticus*

The von Bertalanffy growth parameters used for mortality estimation were obtained from previous age-based analysis as $L\infty = 164$ cm and $k = 0.12\ yr^{-1}$ (Tekle-Giorgis, 2002). *L. niloticus* in Lake Chamo becomes liable to the fishing gears at the length of 35 cm and this length is said to be the length at first recruitment (Tr) (Table 3). At a certain age (sayTr), the fish become liable to encounter the gears because they start migrating to the fishing grounds and this age is referred as the age of recruitment to the fishery (Sparre and Venema, 1992).

The *L. Niloticus* of Lake Chamo started to be caught considerably at the length of 49 cm and 49 cm is the age at first capture (Tc).Because starting 49 cm in Lake Chamo are readily captured if they encounter the nets Table 3 (column 2, row 5). After the age of Tr, the vulnerability of the fish to the fishing net increases when they attain a certain age commonly referred as the age of first capture (Tc) (Schnute, 1987). A length composition data prepared for a linear regression analysis was established between X and Y variables for total mortality estimation (Table 3).

**Table 3: Length composition data of *L. niloticus* for length-based catch curve analysis in 2018**

| Length group | Catch | | | X | Y |
|---|---|---|---|---|---|
| $L_1$-$L_2$ | $C(L_1,L_2)$ | $\Delta t\ (L_1,L_2)$ | $(L_1+L_2)/2$ | $t(L_1+L_2)/2$ | $Ln(C(L_1,L_2)/\Delta t)$ |
| 35-42 | 204 | 0.465 | 38.5 | 2.230 | 6.08 |
| 42-49 | 496 | 0.492 | 45.5 | 2.708 | 6.91 |
| 49-56 | 1079 | 0.523 | 52.5 | 3.215 | 7.63 |
| 56-63 | 1954 | 0.558 | 59.5 | 3.756 | 8.16 |
| 63-70 | 2334 | 0.599 | 66.5 | 4.333 | 8.27 |
| 70-77 | 2392 | 0.645 | 73.5 | 4.954 | 8.22 |
| 77-84 | 2129 | 0.699 | 80.5 | 5.625 | 8.02 |
| 84-91 | 1867 | 0.763 | 87.5 | 6.355 | 7.80 |
| 91-98 | 1488 | 0.840 | 94.5 | 7.154 | 7.48 |
| 98-105 | 846 | 0.934 | 101.5 | 8.039 | 6.81 |
| 105-112 | 583 | 1.052 | 108.5 | 9.029 | 6.32 |
| 112-119 | 321 | 1.205 | 115.5 | 10.152 | 5.58 |
| 119-126 | 175 | 1.409 | 122.5 | 11.451 | 4.82 |

Using the von Bertalanffy growth parameters and the annual length-frequency data, the total catch curve was estimated by applying the length converted catch curve analysis (Figure 1).

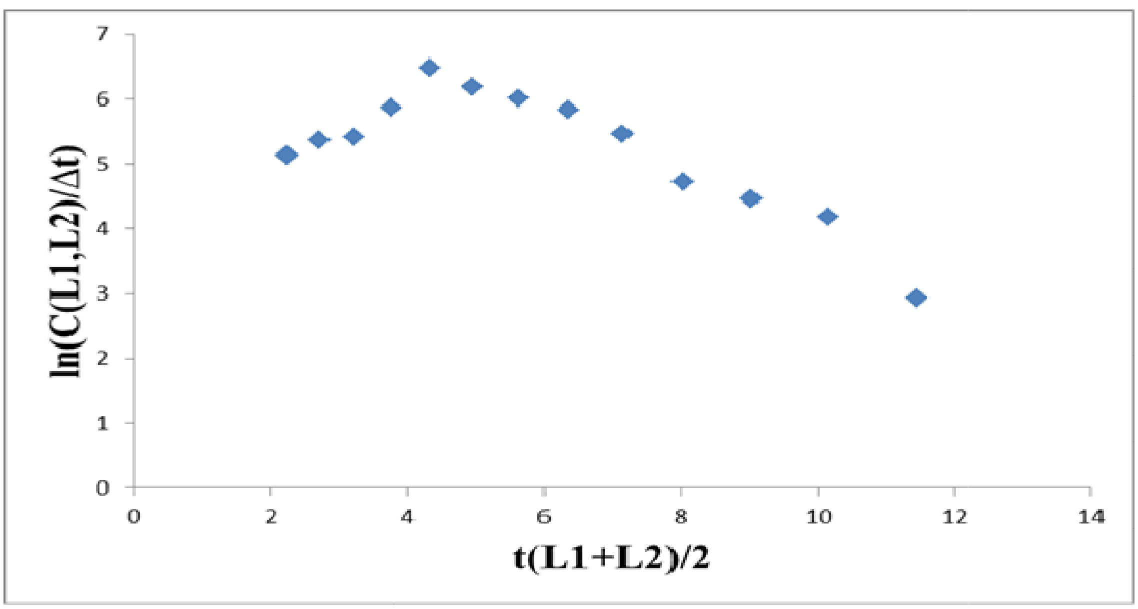


**Figure 1: Length-based total catch curve of *L. niloticus* from Lake Chamo**

For total mortality (Z) estimation, the data points that did not fall on straight line were the data of the youngest age groups and them were excluded as they had not yet attained the age of full exploitation (Figure 2). The slope of the regression line (b) is -0.5674 and hence, the estimated total mortality (Z) was 0.5674 $yr^{-1}$and it was low due to exclusion of youngest age groups as they did not fall on straight line. Of the total mortality, natural mortality (M) and fishing mortality (F) was 0.28 $yr^{-1}$ and 0.29 $yr^{-1}$, respectively. Using these mortality estimates, the exploitation rate (*E*) was computed as 0.51 and indicates slightly overexploitation. The exploitation rate (*E*) equal to 0.5 is considered as an optimum level of exploitation; whereas less than 0.5 refers to under exploitation and greater than 0.5 refers to overexploitation (Gulland, 1971).

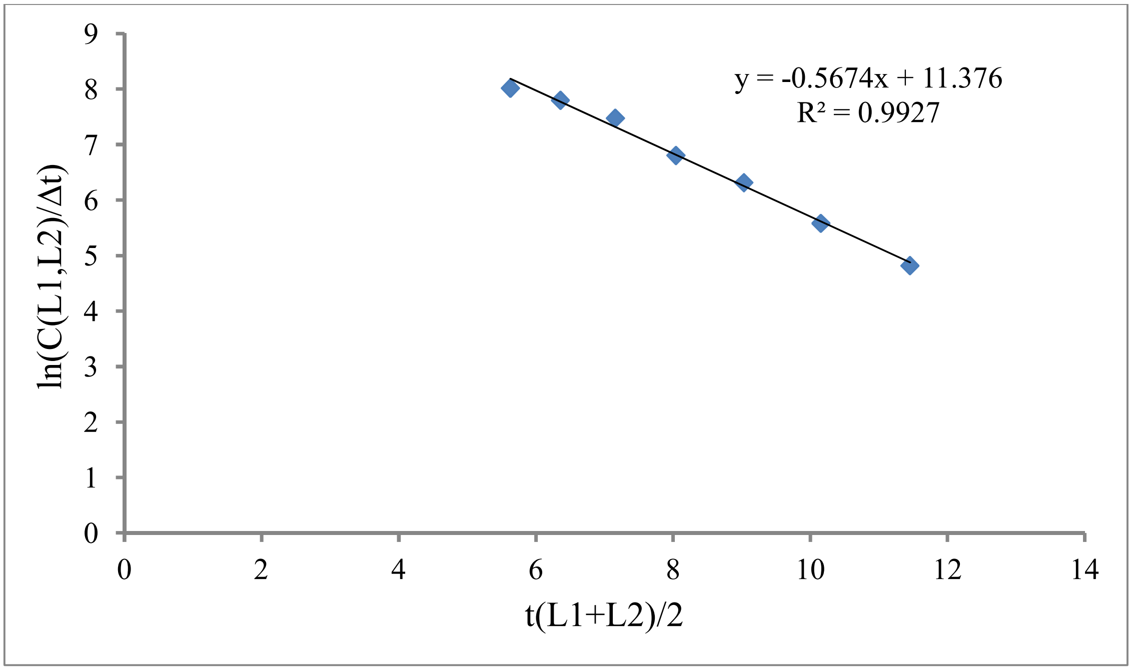


**Figure 2: Linearized length-based catch curve of *L. niloticus* from Lake Chamo**

### 3.4. Estimated population sizes and fishing mortalities

The estimated population number and fishing mortality coefficient by length group is indicated in Table 4. The estimated annual recruitment of *L. niloticus* in Lake Chamo was about 50,000 as indicated in Table 4 (column 9; row 3). Overall, about 0.25 million *L. niloticus* population were estimated to exist in the fished part of the lake as obtained by summing the population numbers of the respective length groups Table 4 (column 9). This estimate belongs to the population of fish excluding the area of the lake protected for fish breeding. Even if it is said to be there is a protected area for breeding, there is a problem of illegal fishing practices taking place in the area. As shown in Table 4 (column 4), the length groups' 35 cm to 70 cm fish shouldered heavy fishing mortality rate bearing above 0.5 fishing mortality per year. This indicates that, the *L. niloticus* stock of Lake Chamo is heavily exploited and removed before their age of maturity.

**Table 4: Estimated population numbers, fishing mortalities and other parameters by length groups for the *L. niloticus* in 2018**

| Length group (L1-L2) | Catch C(L1,L2) | F(L1,L2) | H | Δt (L1,L2) | (L1+L2)/2 | X t(L1+L2)/2 | Y Ln(C(L1,L2)/Δt) | N(L1) |
|---|---|---|---|---|---|---|---|---|
| 35-42 | 204 | 0.62 | 1.067 | 0.465 | 38.5 | 2.23 | 6.08 | 50806 |
| 42-49 | 496 | 0.58 | 1.071 | 0.492 | 45.5 | 2.71 | 6.91 | 44468 |
| 49-56 | 1079 | 0.55 | 1.075 | 0.523 | 52.5 | 3.22 | 7.63 | 38329 |
| 56-63 | 1954 | 0.53 | 1.081 | 0.558 | 59.5 | 3.76 | 8.16 | 32147 |
| 63-70 | 2334 | 0.51 | 1.087 | 0.599 | 66.5 | 4.33 | 8.27 | 25726 |
| 70-77 | 2392 | 0.48 | 1.094 | 0.645 | 73.5 | 4.95 | 8.22 | 19644 |
| 77-84 | 2129 | 0.45 | 1.102 | 0.699 | 80.5 | 5.63 | 8.02 | 14239 |
| 84-91 | 1867 | 0.44 | 1.112 | 0.763 | 87.5 | 6.36 | 7.80 | 9797 |
| 91-98 | 1488 | 0.44 | 1.124 | 0.840 | 94.5 | 7.15 | 7.48 | 6249 |
| 98-105 | 846 | 0.36 | 1.138 | 0.934 | 101.5 | 8.04 | 6.81 | 3627 |
| 105-112 | 583 | 0.36 | 1.157 | 1.052 | 108.5 | 9.03 | 6.32 | 2056 |
| 112-119 | 321 | 0.33 | 1.182 | 1.205 | 115.5 | 10.15 | 5.58 | 1031 |
| 119-126 | 175 | 0.15 | 1.216 | 1.409 | 122.5 | 11.45 | 4.82 | 467 |
| Total | | | | | | | | 0.25 million |

### 3.5. Predicting maximum sustainable yield and optimum fishing efforts

#### 3.5.1. *Estimated total annual yield obtained under the current level of fishing*

The estimated total annual yield is presented in Table 5 and the current total yield (102.4t) pertaining to the respective length group was obtained by multiplying the total catch of the respective length group by the corresponding mean weight values. To obtain this amount of yield (102.4 t), 17,885 nets were applied annually in the lake. In the current investigation, the fishing effort was greater than $f_{MSY}$(9007) which indicates a state of over fishing.

According to Mulugeta and Mereke (2016), the estimated annual yield between the years 2011-2015 ranged from 250-397 tons per year. The total estimated annual yield obtained in the current investigation (102.4 t) was reduced by three folds than in the previous findings. The drastic decline in catch and yield might be due to the increased effort and reduction in mesh sizes of nets. Out of the annual estimated total catch 87.9% was immature or lower than $L_{50}$and might be the main causes for yield reduction.

The increased effort, even without a reduction in mesh size of nets, indicates the presence of recruitment overfishing (Cushing, 1982; Pauly, 1987; FAO, 1999; Israel and Banzon, 2000). Thus, the drastic decline in catch and yield was mainly related to recruitment and growth overfishing with increased effort and reduced mesh size. It is also important to consider that some other factors such as buffer zone agricultural practices, siltation, the application of monofilament nets, lack of co-management and lack of political consideration for monitoring and evaluation are some specified problems taken as a reason for the drastic decline in the amount of catch and yield.

**Table 5: Estimated total yield obtained from *L. niloticus* by length group under the current level of fishing effort in 2018**

| Length group L1-L2 | Catch C(L1,L2) | F(L1,L2) | (L1+L2)/2 | X t(L1+L2)/2 | Y Ln (C(L1,L2)/Δt) | N(L1) | Mean wt (kg) Wbar | Current Yield/yr (kg) Y(L1,L2) |
|---|---|---|---|---|---|---|---|---|
| 35-42 | 204 | 0.62 | 38.5 | 2.23 | 6.08 | 50806 | 0.67 | 137 |
| 42-49 | 496 | 0.58 | 45.5 | 2.71 | 6.91 | 44468 | 1.12 | 554 |
| 49-56 | 1079 | 0.55 | 52.5 | 3.22 | 7.63 | 38329 | 1.73 | 1866 |
| 56-63 | 1954 | 0.53 | 59.5 | 3.76 | 8.16 | 32147 | 2.54 | 4955 |
| 63-70 | 2334 | 0.51 | 66.5 | 4.33 | 8.27 | 25726 | 3.56 | 8313 |
| 70-77 | 2392 | 0.48 | 73.5 | 4.95 | 8.22 | 19644 | 4.84 | 11571 |
| 77-84 | 2129 | 0.45 | 80.5 | 5.63 | 8.02 | 14239 | 6.39 | 13605 |
| 84-91 | 1867 | 0.44 | 87.5 | 6.35 | 7.80 | 9797 | 8.24 | 15392 |
| 91-98 | 1488 | 0.44 | 94.5 | 7.15 | 7.48 | 6249 | 10.43 | 15520 |
| 98-105 | 846 | 0.36 | 101.5 | 8.04 | 6.81 | 3627 | 12.98 | 10980 |
| 105-112 | 583 | 0.36 | 108.5 | 9.03 | 6.32 | 2056 | 15.92 | 9286 |
| 112-119 | 321 | 0.33 | 115.5 | 10.15 | 5.58 | 1031 | 19.27 | 6183 |
| 119-126 | 175 | 0.15 | 122.5 | 11.45 | 4.82 | 467 | 23.07 | 4038 |
| Total | | | | | | 248,586 | | 102.4t/yr |

### 3.5.2. Predicted yield obtained under different levels of fishing pressure

The new F values shown in Table 6 (column 4) are 0.5 times the value of the current fishing mortalities at which the MSY obtained. The estimated MSY of *L. niloticus* in Lake Chamo was 74 tons per year (Table 6, column 9) which would be obtained with $f_{MSY}$ of 9,007 nets per year (Figure 3). The MSY(74 t) was lower than the current yield (102.4 t) and the current yield showed 27.73% yield increments which indicates *L. niloticus* of Lake Chamo is overfished. Therefore, the current fishing effort should be reduced by 50% to keep the sustainability of *L. niloticus* in Lake Chamo. Out of the total annual catch 87.9% were immature or below $L_{50}$.

**Table 6: The MSY obtained under length-based Thompson and Bell yield prediction model for *L. niloticus* of Lake Chamo in 2018**

| Length group L1-L2 | Catch C(L1,L2) | Mean wt (kg) W bar | Changed F | Changed Z | Changed N | Changed death D(L1,L2) | Expected catch C(L1,L2) | Expected Yield (kg/yr |
|---|---|---|---|---|---|---|---|---|
| 35-42 | 204 | 0.67 | 0.31 | 0.59 | 50806 | 12156 | 6425 | 4303 |
| 42-49 | 496 | 1.12 | 0.29 | 0.57 | 38649 | 9418 | 4813 | 5372 |
| 49-56 | 1079 | 1.73 | 0.27 | 0.55 | 29232 | 7316 | 3629 | 6275 |
| 56-63 | 1954 | 2.54 | 0.26 | 0.54 | 21916 | 5718 | 2789 | 7071 |
| 63-70 | 2334 | 3.56 | 0.25 | 0.53 | 16198 | 4404 | 2100 | 7482 |
| 70-77 | 2392 | 4.84 | 0.24 | 0.52 | 11794 | 3354 | 1561 | 7553 |
| 77-84 | 2129 | 6.39 | 0.23 | 0.50 | 8440 | 2509 | 1130 | 7220 |
| 84-91 | 1867 | 8.24 | 0.22 | 0.50 | 5931 | 1877 | 833 | 6870 |
| 91-98 | 1488 | 10.43 | 0.22 | 0.50 | 4054 | 1386 | 614 | 6404 |
| 98-105 | 846 | 12.98 | 0.18 | 0.46 | 2668 | 926 | 364 | 4720 |
| 105-112 | 583 | 15.92 | 0.18 | 0.46 | 1742 | 666 | 263 | 4185 |
| 112-119 | 321 | 19.27 | 0.16 | 0.44 | 1075 | 444 | 165 | 3185 |
| 119-126 | 175 | 23.07 | 0.075 | 0.35 | 632 | 632 | 134 | 3101 |
| Total | | | | | | | | 74t/year |

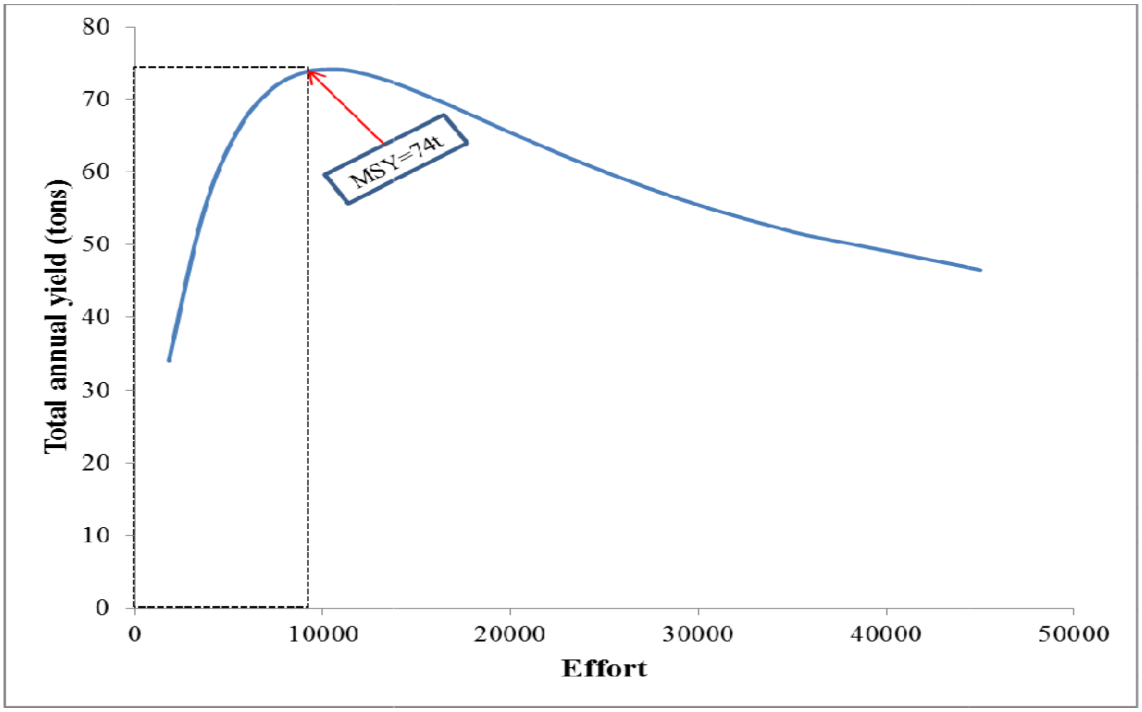


**Figure 3: Maximum sustainable yield and fishing effort of *L. niloticus* in Lake Chamo**

## 4. Conclusions and Recommendations

The *Lates niloticus* stock in Lake Chamo is under heavy fishing pressure. The current fishing effort (17,885) is twice greater than the effort of maximum sustainable yield (9,007) and also found to be narrower mesh size (20 cm) than the recommended minimum mesh size as 28 cm. Consequently, the *L. niloticus* annual catch were found to be insufficient due to heavy fishing pressure and were highly dominated by fish sizes lower than the $L_{50}$ reported for this specie. Thus, the immature number of *L. niloticus*(87.9%) populations of Lake Chamo is exposed to heavy fishing pressure and hence, conclude that, the stocks are experiencing both growth and recruitment overfishing.

The estimated current annual yield (102.4t) was greater than the MSY (74 t) and indicates that the *L. niloticus* of Lake Chamo is overfished. In summary, the future yield status of Lake Chamo is under the status of being depleted with the respective fish species in this study and the fish resource utilization of Lake Chamo calls for urgent management action for conservation and sustainable use. To keep the sustainability of the resource, conservation, rehabilitation and co-management practices should be applied. The nets should be also enforced urgently to protect the capture of immature fish thereby minimize and eventually control growth overfishing.

### Conflicts of Interest

The authors declare that there is no conflict of interest in publishing the manuscript in this journal.


### Acknowledgements

I would like to express my deep gratitude to my late research advisor Dr. Yosef Tekle-Giorgis for his invaluable support and patience in guidance whom this piece of work remembers forever. I would like to thank the Southern Agricultural Research Institute for funding.


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