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Wisdom at the source of the Blue Nile

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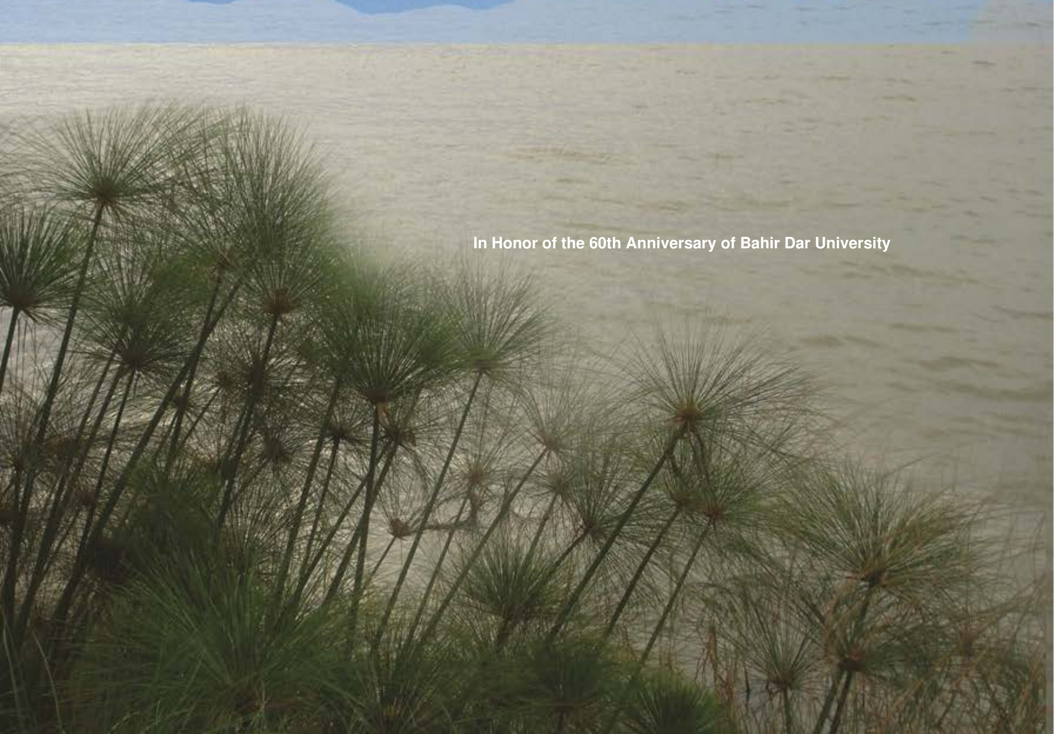

In Honor of the 60th Anniversary of Bahir Dar University

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This publication is an attempt to honor the 60th Anniversary of the establishment of Bahir Dar University (1963 – 2023), which was colorfully venerated on June 11, 2023.

Bahir Dar University, as a higher learning institution, mainly targets the area hosting it, but also beyond. This special issue gives a bird's eye view of some of the best science and technology research activities carried out in Ethiopia over the years. That means it deals with some of the research activities done nationwide and not only here at Bahir Dar University. So far, Ethiopian Journal of Science and Technology has produced hundreds of journal articles in various fields of science and technology and serious readers wanting to know more about the research activities of Bahir Dar University are advised to see the African Journals Online website for details of the various research outputs.

# Editorial Team

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# Dedication

We dedicate this work to those reviewers who toiled day and night often free of charge to get deadlines met and authors who worked hard to generate good scientific data for the betterment of mankind.

# Acknowledgements

We are grateful to Dr Firew Tegegne, who hinted that the journal complements the 60th Anniversary Celebration of the founding of Bahir Dar University by producing a special issue of its own.

# Foreword

It is with great delight we present to readers this special issue of the Ethiopian Journal of Science and Technology (EJST) containing articles in honor of Bahir Dar University's (BDU) 60 years of fountaining wisdom at the source of the Blue Nile (since June 11, 1963)! Established by merging two proud Higher Learning Institutions (HLIs) of Ethiopia, i.e., Bahir Dar Polytechnic Institute (1963) and Academy of Pedagogy (1972), BDU can be taken as a model of establishing HLIs in Ethiopia – evidence being its unique academic programs that produced scholars who played a pivotal role in the country's development and beyond. Bahir Dar University was the first HLI in Ethiopia to spearhead the differentiation of Universities by declaring its ambitious vision of becoming one of the top 10 premier research Universities in Africa by 2025. This paid off as the former Ministry of Science and Higher Education ranked it 1st to become a research University. To realize its vision, BDU aggressively launched postgraduate programs of relevance, and established research centers on priority areas including, but not limited to, science and technology. National and international conferences blossomed, platforms to rethink and balance indigenous knowledge (contextualized education) with contemporary knowledge and ultimately serve as bridges between civilizations and continents. In line with these initiatives, EJST was launched as a medium of science communication! Currently, EJST is an accredited journal – thanks to its editors, reviewers and authors who may contribute from anywhere, linking scholars in a world where there are extensive asymmetries in researchers' ability to access and create knowledge.

Firew Tegegne Amogne (PhD)

President, Bahir Dar University

# Preface

This is the first special issue of the Ethiopian Journal of Science and Technology (EJST). Normally a special issue focuses on one topic at a time but in the current case, we opted to use it to wrap up the history of some selected science and technology research efforts in Ethiopia. To do so, we invited interested authors on the website to contribute to the special issue by submitting historical accounts of authoritative research endeavors that were undertaken over the years in Ethiopia. We received a number of articles from distinguished scholars, reviewed them and here they are. The purpose of the special issue was to complement the 60th Anniversary of the founding of the University. The contents of the special issue were an attempt to highlight previous research efforts in selected fields of science and technology and also show the future thrust. Ethiopian Journal of Science and Technology was one of the oldest, largest and most successful journals launched after the establishment of the university (first at the university level, then inherited by Science College). The journal was launched in 2002, about two years after the establishment of Bahir Dar University by merging two former higher learning institutions already operational in Bahir Dar, i.e., Polytechnic Institute (est. June 1963 G.C.) and Bahir Dar Pedagogy College (est. 1972 G.C.). Now there exist as many as eight campuses and 15 academic units scattered all over the city (compared with only two at the founding of the university). The title of the journal at first was “Ethiopian Journal of Technology, Education and Sustainable Development,” which was soon changed to the current name of EJST.

The scope of the journal was science and technology, which was very broad. It included sciences that contribute to the improvement of human, animal and environmental health, food production and processing, energy, and engineering of all types, etc. At first, the journal was run by an editor-in-chief and a managing editor, when it was run at the university level, but after its transfer to Science College, it was run by an editor-in-chief and a bunch of associate editors. Since 2002, a total of over 200 papers have been published in the last 16 volumes. The number of articles varied between five and eight per issue. The number of issues per year was two at first, then three since its transfer to Science College. The journal was interrupted once for logistical and manpower problems at the time when

Business Process Re-engineering (BPR) was implemented in the university and nationwide. Geographic coverage of the journal was never specified, which meant that papers could be accepted from anywhere. Papers were received, reviewed and published largely from domestic sources (Ethiopia), but also from Africa – such as Nigeria (the bulk of it), Uganda, Tanzania, Malawi, Rwanda – from Asia (like India), etc.

The journal has been recognized and accredited by the Bahir Dar University Senate and the Ethiopian Ministry of Education. This year (2023), it has been upgraded from a 1-star journal to a 2-star journal by African Journals Online (AJOL). We have submitted a request to Scopus to be indexed although we lack some of the basic criteria they want from the journal such as geographically diverse and an international mix of the editorial board. These criteria are the most important components that we need to address in the near future, i.e., reconstituting the editorial board yet again as per the requirements from Scopus and other international indexers. Nevertheless, the journal is indexed by other agencies including AJOL.

We hereby invite researchers and academicians alike to continue submissions to our journal, which has a bright future.

The Editorial Team

# Textile and clothing production and trading- the way to industrial economy development

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**ABSTRACT**

The expansion of the textile and clothing industries is inextricably linked to the socioeconomic advancement of all nations in the world that are struggling to come out of poverty and backwardness. The fact that the textile and clothing industries have successfully transitioned from an agricultural to a manufacturing-based economy justifies the continued use of this strategy by all emerging nations worldwide. From Europe to North America, then to Asia, South America, and other nations on other continents, the textile and clothing sector has been successfully used for socio-economic transformation. In every country it traversed, the textile and clothing guaranteed socioeconomic progress. Ethiopia started the implementation of agricultural development led industrialization (ADLI) plan in 1995 after realizing the significance of textile and clothing for its socioeconomic development. Unfortunately, despite the potential the country has for the development of the textile and apparel industries, the plan has not been implemented effectively, and as a result, the growth of the industry and the economic and social outcomes from the sector have not been as substantial. Thus, the Ethiopian textile and garment clothing sector industries are facing multiple challenges such as backward linkage, delivery and demand side linkage, employee-related problems, poor utilities and facilities, and weak control and coordination. The production and trade of textiles and clothing is the only industrial sector that contributes to industrial economic development for the least developing nations. Therefore, policy revision and problem-solving are essential to maintain this sector's industrial development in Ethiopia in order to realize a large industrial economy in the country.

**Keywords**: Textile; Clothing; Socioeconomic; Manufacturing and Challenges.
**DOI**: https://dx.doi.org/10.4314/ejst.v16iSpecial.1

## INTRODUCTION

The so-called "industrial revolution" started in England in the middle of the 1700s. Science and capital were for the first time combined by the means of the industrial revolution to address production-related issues (Dickerson, 1995). Prior to 1750, the majority of English households lived on farms or in small villages,

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and poverty was widespread in England at the time, just like it is now in Ethiopia. In England, the Industrial Revolution led to the establishment of the first textile factories and mills, which gave rise to a factory system. In the early to middle decades of the 19th century, New England underwent a major social transformation that transformed it from a rural, agrarian society to an urban, industrial society, drawing young men and women to the textile factories. Ethiopia needs this type of socioeconomic development badly since around 80% of its people are involved in substandard small-scale farming.

The first clothing factory was built in Philadelphia, United States of America (USA), to create uniforms for the War of 1812, following the development pattern of the textile factories in England (Kidwell and Christman, 1974). The key characteristics of the apparel sector are its labor-intensive, ease of entry with little start-up investment and technical know-how, minimal worker training, and ease of mastery of the industry's manufacturing tools. The growth of the textile and garment industries in England and the USA led to the first cross-border migration of labor and capital. Over 62 million individuals, largely from Europe, traveled between 1820 and 1930, with roughly 35% settling in the United States. Ethiopia has been involved in this area of industry since 1995 with its Agricultural Development Led Industrialization (ADLI) program, having learned the significance of textile and clothing manufacturing and commerce from foreign experience. To shift Ethiopia's economy from one that was centered on agriculture to one that was manufacturing-based, this strategy prioritized the production and marketing of textiles and clothing. As a result, this review's discussion of the relevance of global textile and apparel production and trade in Ethiopia’s context is presented succinctly.

## THE GLOBAL SCENARIO FOR TEXTILE AND CLOTHING MANUFACTURING

Due to its low fixed costs and concentration on labor-intensive manufacturing, the production of textiles and clothing serves as a foundation for national growth and is frequently the traditional starting industry for nations engaged in export-oriented industrialization (Gereffi, 1999; Adhikari and Weeratunge, 2006). Because most countries manufacture for the global market, this is one of the most international sectors. By the 1960s, rising imports from low-wage developing nations had an influence on both the textile and clothing sectors in the majority of developed nations.

### Textile and clothing manufacturing as sensitive and complex industrial sector

Particularly responsible for the decline in the production of industrialized nations as a share of global manufacturing was Japan, the then-developing country with expanded production capacity. During the 1920s through the 1950s, Japan's economic expansion followed the earlier trend in the USA and certain European nations by mainly depending on the textile and clothing industries to drive the industrialization process. Japan became the world's top exporter of cotton textile goods in 1933 (Dickerson, 1995). Other less developed countries started to produce and export cotton goods after Japan. Hong Kong, Taiwan, South Korea, India, China, and Pakistan soon joined Japan in exporting increasing volumes to the industrialized nations (Figure 1). Several emerging nations and a few countries in Eastern Europe started to model their economic development plans after those of industrialized nations in the 1950s and 1960s. The industrialized world has higher labor costs than developing nations, which reduces its competitiveness and forces merchants to outsource portions of the production process. Following the example of Japan and other industrialized nations, China put a lot of focus on labor-intensive manufacturing as part of its 1979 economic reform in an effort to expand exports.

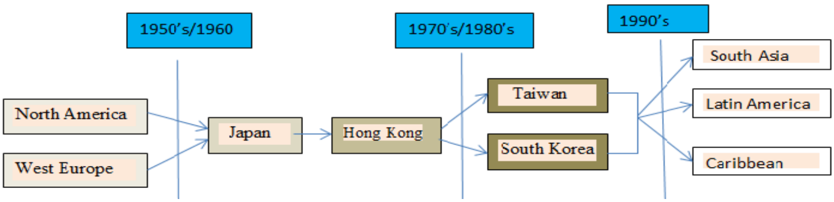


Figure 1**.** The historical perspective of textile and clothing industries global travelling

The comparative advantage in manufacturing is lost as economies become wealthier and salaries rise, and the emphasis instead switches to high-value-added goods or other produced goods with lower labor intensity (Adhikari and Weeratunge, 2006). Suppliers must be able to offer full package options that expand their capabilities to other parts of the value chain, including design, inventory management, and transportation of goods, and adopt the right technologies to facilitate this transition in order to operate effectively in the current textile and apparel global trading environment (Technopak, 2007). On the other hand, the need for supply chain openness has grown in both the US and the EU due to the rising consumer demand for greater social and environmental standards. The leading companies want to learn more about their suppliers and make sure they maintain the brand guidelines (Sauls, 2008).

## The top international manufacturers and exporters of textiles and clothing

With ongoing growth of their positions in the sector, China, Bangladesh, India, Vietnam, and Germany have been the main winners of the competition in textile and clothing production and export to the worldwide market (Gereffi and Frederick, 2010). China, Bangladesh, Vietnam, and India are the top exporters of traditional textiles and clothing worldwide, whereas Germany is the top exporter of technical textiles. Since the early 1970s, the global clothing sector has been growing quickly and employing tens of millions of people in some of the least developed nations on the globe. Table 1 displays the annual export revenue and employment generated in the main exporting nations. In terms of yarn, fabric, dyeing, printing, finishing, and accessories, China completely meets its local demand (Wazir Advisor, 2021). Moreover, China exports machineries for spinning, weaving, knitting, dyeing, printing, finishing, and testing, as well as equipment and sewing machines for clothing manufacture. China's textile industry has a production capacity that exceeds more than half of the whole world market (Alam *et al*., 2020). One of the key sectors in India that significantly contributes to the GDP of the country is the textile and garment sector (Giri and Rai, 2013).

The industry sector provides around 14% of industrial production, 4% of GDP, and 17% of India's export revenue (Chandra, 2005; CUTS International, 2020). Three decades ago, Bangladesh began participating in the global textile and clothing export market without having enough backward links (Houkokusho, 2012). According to Masum and Inaba (2015), Bangladesh's textile and clothing industry generates 82% of the nation's export revenue and contributes 23% of the nation's gross domestic product (GDP).

Table 1. Global textile and apparel leading exporter - $USD, 2019

| Country | Exports | | | Market share (%) | Direct employment (millions) |
|---|---|---|---|---|---|
| | Textile | Apparel | Total | | |
| China | 134.6 | 149.9 | 284.5 | 34 | 30 |
| Vietnam | 10.2 | 33.7 | 43.9 | 5 | 1.6 |
| Bangladesh | 1.8 | 40.9 | 42.7 | 5 | 5.1 |
| Germany | 15.5 | 23.8 | 39.3 | 5 | - |
| India | 20.2 | 16.2 | 36.4 | 4 | 35 |

In Vietnam, textile and clothing exports increased at a spectacular average annual growth rate of 29% from 1991 to 2000, outpacing the nation's overall export development (Berger and Lester, 2001). Similar to Bangladesh, Vietnam's exports of textiles and clothing increased from $1.96 billion to $2.7 billion during 2001 and 2002. With a global market share of almost 45% in the technical textiles sector, German enterprises are world leaders (Heymann, 2011).

## THE GLOBAL TEXTILE AND CLOTHING TRADE

The textile and clothing industry has long been a significant sector of the worldwide economy, ranking second only to agricultural products in terms of value in 2018 (IFPRI, 2020). Figure 2 depicts the worldwide commerce in textiles and clothing items, which reached $839 billion in 2019 and is projected to reach

$1 trillion by 2025 (Wazir Advisors, 2021). According to the WTO (2017), the EU, USA, and Japan account for 76.2% of all textile clothing imports worldwide, making them the top three garment importers globally. Other nations, such as the Russian Federation, Canada, Switzerland, the United Arab Emirates, Australia, South Korea, Norway, Mexico, China, and others, import the remaining 24.8% of the textile and clothing items (Gereffi and Frederick, 2010). Global customers or importers place demands on manufacturers and exporters, including those for less expensive goods, better quality, quicker lead times, and labor standards (employment terms, pay from employment, and working conditions) (Keane and Velde, 2008).


Figure 2. The global textile and clothing trade trend with category-wise share ($ Billion) (Source: Wazir Analysis, 2021)

## ETHIOPIAN TEXTILE AND APPAREL PRODUCTION AND TRADING SCENARIO

The fourth industrial revolution is now taking shape globally using modern technology. The first industrial revolution began in England with the industrialization of textile production, and other industries later adopted this model. As a result, Ethiopia is currently implementing all technological vicissitudes resulting from the first through fourth industrial revolutions. On the other hand, Ethiopia's current socioeconomic state is comparable to how English people lived before the first industrial revolution in the 1750s. Similar to how the majority of English people lived before the industrial revolution, around 80% of Ethiopia's population today lives in rural farming communities where poverty is rife.

The first industrial revolution movement was sparked by the then-worst socioeconomic situation in England, and as a result, New England arose with improved social status and economic progress. The industrial revolution has inspired other countries to model their socioeconomic growth after that of New England's textile manufacturing sector. The production and trade of textiles and clothing was utilized by all industrialized nations to support the growth of their manufacturing industries. Thus, Ethiopia's expanding textile and clothing sector is a necessity step if it hopes to rescue the nation from its current economic predicament. Production in the textile and clothing sector helps Ethiopia transition from a resource-based economy to an industrial manufacturing one. Because of their labor-intensive nature, ease of entry, low capital requirements, and ability to be learned quickly, textile and clothing manufacturing and commerce are suitable for the current socio-economic scenario in Ethiopia. By the creation of mills or industrial villages, the bulk of the rural people will progressively transition from being rural to urban residents in terms of socialization (Cooper, 2013).

## Ethiopian potential for the rapid expansion of the textile and clothing industry

The availability of plentiful labor at a low price, which is Ethiopia's key comparative advantage, makes it the most suited country for the manufacture and trading of textiles and clothing. Ethiopia is a fortunate country in this aspect since, out of an estimated 115 million people, 70% are young and trainable. The capacity of the nation to produce cotton might be seen as a second comparative advantage, especially for the expanding cotton-based textile and garment industry. With a total land area of 1,127,127 $km^2$, Ethiopia is the $27^{th}$ largest nation in the world (Mohajan, 2013). Nearly 3 million hectares of the nation's land area are potentially suitable for cotton production, but only 3% of that area is currently under cultivation for cotton (European Commission, 2021; Tiliksew *et al.*, 2021). This figure illustrated the enormous potential for widespread cotton cultivation in the country. The third comparative advantage Ethiopia has for a thriving textile and clothing industry is arguably its geographical location between Europe and Asia. The majority of customers of textile and clothing products are European nations, whereas the majority of suppliers of raw materials for textile and clothing manufacture are Asian nations. Due to Ethiopia's existing production situation, in which its backward links to the manufacturing of textiles and clothing are quite weak, the proximity to Asia is an opportunity.

## The present production and trading scenario of Ethiopia's textile and clothing industry

According to data from Ethiopia, the textile and clothing sector has expanded at an average rate of 51% during the past ten years. Throughout this time, licenses have been issued for more than 65 foreign international textile and clothing investment projects (Kohan Textile Report, 2022). There are now 176 clothing and 52 textile industries in the sector (ETIDI, 2018). Ethiopia's textile and clothing industry’s output and trade are inconsistent, according to Beatrice *et al.* (ND). The Gross Value of Production (GVP), which started at $2 million in 1995/1996 and climbed progressively to $35.5 million in 2006/07 before abruptly dropping to $2.3 million in the years that followed, surged dramatically once again to $78.1 million in 2009/10. According to New Business Ethiopia, the country's export value for textiles and clothing reached $126 million in 2021.

The share of exporting textile and clothing products by FDI firms accounted for 80% of total exports in 2017 (Staritz and Whitfield, 2019). There are currently 13 industrial parks around the nation where textiles and clothing are produced with a focus on export. The present employment level in Ethiopia's textile and clothing industry is anticipated to reach 80,000 in 2017 (Clasmann and Anne-Beatrice, 2017). According to Beatrice *et al.* (ND), the products of Ethiopia's textile and clothing sector range from carpets and towels to clothing and uniforms. The export of textile and clothing products includes items like t-shirts, sportswear, trousers, work clothing and safety clothing, undergarments, jackets, home textiles, bags, and scarves with ethnic motifs.

**The competitive challenges of Ethiopia's textile and apparel industry**

Ethiopia's textile and clothing industry is struggling with production and marketing difficulties. The supply of cotton, fabrics, accessories, dyes, and auxiliary materials constitutes backward linkage production challenges. The workforce's skill level is low, and as a result, their effectiveness is inadequate. Additionally, import/export regulations are complicated, which affects lead times, product quality, and production costs (Beatrice *et al.*, ND). According to Beatrice *et al.* (ND), the constraints facing the Ethiopian textile and apparel industry sector are backward linkage, delivery and demand-side linkage, employee related, utility and facility-related, and managing and coordination limitations. Figure 2 illustrates these constraints and how they relate to one another.

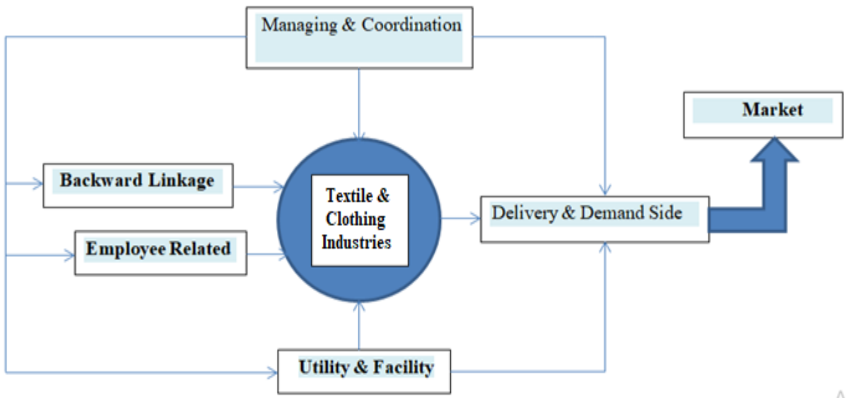


Figure 2. The difficulties that Ethiopia's textile and clothing industry is currently confronting

**Backward linkage challenge**

Ethiopia has a shortage of locally produced fabrics, trims, and usable cotton goods; thus, these materials must be imported from countries like China, India, Turkey, and Pakistan. Local cotton production meets only 60% of the textile and clothing industry's needs and is expensive and of subpar quality. Most of the textile sector uses old or obsolete machinery, and the fabric production is devoted to domestic garment production (bed sheets, working cloth, etc.). The domestic input-producing sector offers a small selection of low-quality accessories. As the majority of the clothing accessories are imported, they may be more expensive than most of their rivals, especially those in Asia, who profit from a developed industrial sector and technological expertise. The flexibility of Ethiopian producers to adapt to customer needs is hampered by such limitations.

**Employee related challenges**

The majority of textile and clothing industry employees do not have an industrial work culture. Finding qualified workers who will stay is a big problem in the clothing manufacturing sector, where worker efficiency is quite low at 25% and absenteeism is high, accounting for 23% in some clothing manufacturing companies. Technical and soft skills are generally lacking among textile and clothing industry employees. The average monthly employee turnover rate for the textile and clothing sector is 8%, or 100% annually (Mihretu and Lilobet, 2017). Throughout the value chain of manufacturers, importers, and retailers, the stability of the workforce in the textile and clothing sectors is crucial.

**Utility and facility challenge**

The lead time of the customer agreement that governs the planned output of the clothing industry is impacted by often occurring electrical outages. Another difficulty is that internet connectivity is frequently erratic and severely constrained. Moreover, the absence of regional certification organizations makes it difficult for the local textile and clothing industries to sell their goods to international consumers. Further difficulties include the inability to get pre-shipment financing and the restricted availability of the foreign currency required for the import of the inputs (Beatrice *et al.*, ND).

**Delivery and demand side challenges**

Transportation, port facilities, public services, and other after-production components are included in the forward or delivery connections. Transporting products for shipment requires a lot of time, is delayed by customs clearance and port authorities, and is somewhat expensive. Transport time from Ethiopia to the EU might take up to 40 or 45 days for all possible reasons (Beatrice *et al.*, ND).

Consumer expectations, prevailing trends, impending events, seasonal fluctuations, etc., which are connected to demand forecasting, and, as a result, the capacity to create the ideal product need to be understood (Houkokusho, 2012), The clothing product has an extremely wide range, a short-lived, rigid supply chain, a volatile, unpredictable demand, and a restricted life cycle (summer items, winter products, etc.). These initiatives are a result of the companies' research and development departments. This covers customer analysis, demand forecasts, product design, order confirmation, and bilateral relations.

### Management and coordination

The textile and clothing sectors need effective management. The industry won't be competitive on the worldwide market if the management doesn't know what they're doing. The management must continuously develop the workforce via training in both hard and soft skills. Basic skill development cannot make a workforce productive, disciplined, and responsible on their own. It is frequently the case that there is a lack of coordination between service providers (such as those who provide electricity, internet, customs clearance, transportation, and port facilities) and textile and clothing manufacturers, which can have an impact on industry production, productivity, and lead times. In consequence, this will reduce the industry's ability to compete in the worldwide trade and manufacture of textiles and clothing.

## THE NECESSARY INTERVENTION

No country in the world has achieved industrial development without first entering the textile and clothing manufacturing and trading sectors, as learned from the experience of all industrially developed nations. Therefore, the production and trade of textiles and clothing are essential to the socioeconomic development of Ethiopia because they generate significant employment opportunities, boost export revenues, and transform rural residents into city dwellers through the creation of mill or industry villages. The following contributing rudiments for the industrial sector's growth must be prioritized in order to reach the necessary developmental stage.

### Enhancing education and training

Ethiopia is only a marginal supplier to the global textile and clothing market, and an upgrade to the level of preferred supplier, full-service provider, or strategic supplier is necessary to benefit more from the global value chain. Investing in education and training to address skills gaps is essential for industrial upgrading. In this regard, Bahir Dar University has provided 5564 graduates with qualifications ranging from diploma to doctoral (PhD), making significant contributions to human resource development, research, and deployment in the textile and clothing industrial sector. Ethiopian technical and vocational training institutions also provide instruction in industrial operations. However, both universities' and technical and vocational training institutions need to improve their quality of education and training to keep up with international competitiveness in textile and clothing manufacturing and trade. Therefore, it is required to further strengthen the sector's education and training with additional investment and focused follow up. In addition, due to the importance of textile and clothing production and trading for the socioeconomic growth of the nation and the reduction of poverty, the sector's education and training need to be handled with the utmost care.

**Promote foreign direct investment or joint ventures to develop vertical capabilities**

Ethiopian companies that manufacture clothing and textiles are able to engage in global supply chains. Skills, expertise, and technology will be transmitted through FDI in addition to capital. They are all viewed as crucial elements for increasing productivity and driving growth (UNIDO, 2004). FDI is a useful way for late-coming Ethiopia to take advantage of technology breakthroughs in textile and clothing manufacturing and commerce far from the technological frontier in order to access new technologies. As a result of commerce with both developed and developing nations, as well as involvement in global value chains due to knowledge spillovers from outside, Ethiopian textile and clothing companies "learn by doing" (Jodie Keane and Dirk Willem Van Velde, 2008). Governments in developing nations have a part to play in crafting industrial policies to make sure that the potential gains from exporting the textile and clothing industries are attached in a way that fosters beneficial learning effects for the larger economy.

**The government's involvement in the manufacturing and trade of textiles and accessories**

The challenges with backward linking that now plague Ethiopia's textile and apparel sector cause it to lag behind global competition. According to the Vietnamese experience, the Ethiopian government must invest in the construction of major cotton farming, complicated textile, and garment accessory manufacturing industries in order to tackle this problem. Ethiopia has a great deal of potential for growing cotton, but the likely locations are far away and lack infrastructure, and private investors are not interested in such investments. To close the growing gap in the production and trade of textiles and clothing, the government must make such an investment. The nation will gain from such government investment in the form of greater employment, increased export revenue, and general socioeconomic growth along the whole value chain of textile and clothing manufacturing and commerce.

## CONCLUSION

The textile and clothing industry is a dynamic sector for investigating less expensive labor for global production. Due to the labor-intensive nature of the textile and clothing manufacturing industries and the fact that labor represents the majority of the industry's production costs, this industry is typically relocated from industrially developed countries to low-income developing countries. For low-income nations aiming for industrial economic growth, the industry's movement pattern is favorable. The textile and apparel sector benefits low-income developing nations in numerous ways, including: ease of entry into the industry, employment opportunities due to the labor-intensive nature of the sector, export earnings from manufacturing, growth of the industrial culture, and capital accumulation for ongoing heavy industrial economic development. With its agriculture development led industrialization strategic plan, Ethiopia, a low-income nation, strategically joined the textile and clothing manufacturing and trade industries in 1995; nevertheless, the sector has not yet considerably increased its share of the world market. The failure to resolve issues confronting the sector industry, such as backward linkage, delivery and demand side linkage, employee related, utility and facility, and managing and coordination constraints may be the root cause of the country's poor performance in textile and clothing production and trade. The issues that the sector industry is presently facing must be resolved by careful planning and execution if the nation is to progress via the manufacturing industry. Moreover, policymakers must update the strategy when the nation strengthens its position in the global textile and apparel production and trade market.

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# Biodiversity: Resources, national capital and politics

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**ABSTRACT**

This article is a brief summary of biodiversity as a concept and its implementation in the world stage and in Ethiopia. Biodiversity is the lifeline for all and needs to be protected whereby every citizen has a stake. Its history goes back in time as an activism at first that later metamorphosed to a full-fledged science. It further grew as a political discourse amongst the policy-makers and scientists. It was subsequently followed by a number of conventions targeted to protecting biodiversity, some of which were realized and others were not. Ethiopia has a special relevance and place when it comes to biodiversity for the rest of the world because of its unique biodiversity and landscape position. Ethiopia has been a center of origin (and domestication) for some plant species and also a center of diversity for others.

**Keywords**: Conservation; Species; Ecosystems; Threats; Biodiversity targets; Community survival

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## INTRODUCTION

What is biodiversity? When living things differ very much, that situation is termed biological diversity, or biodiversity for short. Officially, biodiversity is defined as the variability of all biological organization at all levels in both aquatic and terrestrial life. Walter Rosen coined the term when organizing the gathering held in Washington D.C. in 1986 with the support of Edward Wilson, “The National Forum on Biological Diversity”. The activity was undertaken under the joint auspices of the National Academy of Sciences and the Smithsonian Institute. The group felt that a new catchword was needed to promote nature conservation and to make people aware of the lurking dangers of species extinction (Nieminen, 2001; Sarkar, 2002).

Biodiversity is fundamental for the survival of human beings, be it in agriculture, forestry, industry, export goods, economic output and ecosystem services and functions. The purpose of this review is to show the values and sociopolitical aspects of biodiversity and spark thinking.

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## WHY BIODIVERSITY BECAME SUCH AN ISSUE?

The idea started as scientific and/or activism, though originally conceived to be a scientific tool aimed to achieve certain ends: to prevent worldwide loss of species diversity, to alter the world rapid extinction by catalyzing public interests and actions. Biodiversity as an organizing concept started from the need to communicate and act in a concerted effort (Norton, 2003). However, the 1980s discourse immediately boiled and end up in the UN convention (UN CBD 1992).

The Convention on Biological Diversity opened for signature on 5 June 1992 at the United Nations Conference on Environment and Development (the Rio "Earth Summit"). The Convention's three objectives were the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits arising from the utilization of genetic resources. The Convention has many challenges.

1. Deploy urgent political attention to implementation and support.
2. Concentrate on a core set of actionable targets and national obligations: parties to the Convention on Biological Diversity (CBD) are legally required to develop national strategies and reports. These instruments may sound bureaucratic, but they are the nuts and bolts of an effective global environmental regime.
3. Build a clear vision and a political strategy to fulfill it.
4. May be the fourth is regarding biotechnology. Therefore, during 7-18 December 2022, 196 countries who have signed the agreements are coming together to decide on the best plan of action to reduce biodiversity loss, with a specific obligation on utilizing biotechnology, while limiting its impact on the environment.

## THE CONVENTION OF BIOLOGICAL DIVERSITY AND DEVELOPING NATIONS

Originally, the convention acknowledges the special needs of Least Developed Countries (LDCs), among those of other developing countries:

- Preamble: Parties acknowledge, "special provision is required to meet the needs of developing countries, including the provision of new and additional financial resources and appropriate access to relevant technologies" and, in this regard, note "the special conditions of the least developed countries and small island states".
- Article 20.5: Parties commit to taking "full account of the specific needs and special situation of least developed countries in their actions with regard to funding and transfer of technology".

The Convention has two protocols, both of which take into account the needs of, and commit to cooperating with, developing countries and "in particular" those of LDCs and other groups of countries such as small island developing states (SIDS) and parties with economies in transition:

- **Cartagena Protocol** (2003) on Biosafety amid at Convention on Biological Diversity governs the movement of living modified organisms – LMOs – resulting from modern biotechnology from one country to another. In regard to the establishment of a Biosafety Clearing-House, parties committed to assist parties to implement the Protocol, taking into account the special needs of developing countries. It is said that in particular the least developed and small island developing states among them, and countries with economies in transition as well as countries that are centers of origin and centers of genetic diversity" (Article 20). In regard to capacity-building, financial resources and access to and transfer of technology and know-how, parties commit to cooperating in the development and/or strengthening of human resources and institutional capacities in biosafety in developing country parties, "in particular" the LDCs and SIDS among them, and in parties with economies in transition (Articles 22 and 28).
- **The Nagoya Protocol** (2011) is about access to generic resources and the fair and equitable sharing of benefits arising from their utilization. The parties committed to taking into account the needs of, and cooperating with, developing country parties and "in particular" LDCs, SIDS and parties with economies in transition (Article 22 on capacity; Article 23 on technology transfer, collaboration and cooperation; Article 25 on Financial Mechanisms and Resources).

## BIO-POLITICS

The reason why it grows fast and we like it or not is a politically charged concept as it invoked to further political agenda. The Convention is the only international instrument comprehensively addressing biological diversity. Then come in conflict with other world trade organization treaties. The first African Union (OAU/ STRC, 2000) Model Laws is a legislative framework that addresses these challenges by harmonizing requirements and processes. Second Cartagena Protocol on Biosafety to the Convention on Biological Diversity has been effective since 2003. Then second took more than a decade and end in Nagoya Protocol on Access and Benefit Sharing (ABS) is a 2010 supplementary agreement to the CBD, 1992. The main topics of international biodiversity politics beside conservation are access to biodiversity and its genetic resources, benefit sharing from its use and intellectual property rights. A major problem of this system is the relationship between varying negotiation processes in different fora. Another closely connected problem is contradictory relationship between different regulatory levels at different spatial scales (international, regional, local). Convention on Biological Diversity (CBD), the International Undertaking on Plant Genetic Resources of the Food and Agricultural

Organization (FAO) and the Agreement on Trade-Related Intellectual Property Rights (TRIPS) in the World Trade Organization (WTO).

What is needed to draw attention to on the development agenda in Ethiopia is how the regulation of biodiversity may function in the future. In the official Ethiopian biodiversity politics, protection and appropriation strategies are normally distinguished. Implementation GEF favored some areas and not others. For the national strategy (IBC, 2005), most successes were reached in the field of protection. The "National Biodiversity Strategy" (IBC, 2005) also puts most emphasis on protection. However, it would be an oversimplification to pose protection and abandoning building of infrastructure into the parks and other tourist sites.

The new sustainable development might be challenged by the new Global-trade thinking. Studies have theorized that, in developed countries, multinational co-operations often relocate "dirty" sectors to developing and emerging economies with far fewer environmental treaties and standards to maximize the profit of the weaknesses of developing and emerging blocs. This idea is known as the 'pollution haven' hypothesis (PHH).

The Aichi 20 Biodiversity Targets in 2011 to offer a framework for 2020:

1: Awareness of biodiversity increased,
2: Biodiversity values integrated,
3: Incentives reformed,
4: Sustainable production and consumption,
5: Habitat loss halved or reduced,
6: Sustainable management of aquatic living resources,
7: Sustainable agriculture, aquaculture and forestry,
8: Pollution reduced,
9: Invasive alien species prevented and controlled,
10: Ecosystems vulnerable to climate change,
11: Protected areas increased and improved,
12: Reducing risk of extinction,
13: Safeguarding genetic diversity,
14: Ecosystem services,
15: Ecosystem restoration and resilience,
16: Access to and sharing benefits from genetic resources,
17: Biodiversity strategies and action plans,
18: Traditional knowledge and customary sustainable use,
19: Sharing information and knowledge, and
20: Mobilizing resources from all (Sources: https://www.cbd.int/doc/strategic-plan/targets/T15-quick-guide-en.pdf)

According to the Global Biodiversity Outlook 5 report published by the United Nations in 2020, none of the Aichi biodiversity targets have been achieved at a global level. Out of the 20 goals, only six were partially achieved, 38 have shown progress while 13 have shown no progress. However, the targets such as halving the loss of natural habitats have not been met despite global deforestation rates having decreased by about a third in the past five years compared with pre-2010 levels. Wetlands have continued to disappear and freshwater ecosystems remain critically threatened. The eradication of harmful government subsidies for agriculture, fossil fuels and fishing are barely made, if any, and no progress at all. However, Ethiopia has shown substantial progress in the implementation of the Strategic Plan 2011-2020. It has made substantial progress in the 20 Aichi Biodiversity Targets. The country has registered very good achievements in regard to Aichi Targets 1, 2, 7, 10, 11, 13, 14, 15 and 18, good achievements in regard to Aichi Targets 3, 4, 12, 16, 17 and 19 and fair achievements in regard to Aichi Targets 5, 6, 8 and 9, in the first half of the Plan's period. However, implementation of Aichi Target 20 has been poor (CBD Country Profiles).

Out of the 20 Aichi Biodiversity Targets, Ethiopia has performed "very good", "good", "fair" and "poor" in 9, 6, 4 and 1 targets, respectively (EBI, 2014). How can we get poor in number one unless there is lack of government transparency, given the country received hundreds of million dollars of aid over the years?

## BIODIVERSITY IN AFRICA

Africa is home to a rich and diverse animal, plant, and marine biodiversity that provides critical ecosystem services, drives the continent's economy and serves as buffers to climate change. However, the continent is experiencing a dramatic loss of biodiversity. It is estimated that by 2100, climate change alone could cause the loss of over half of African bird and mammal species, as well as trigger a 20–30% decline in the productivity of lakes (the plant and animal life produced by lakes), and a significant loss of plant species.

Even more immediate are the ongoing threats to African biodiversity from natural habitat loss and degradation (especially from agricultural expansion), direct overexploitation of wildlife and fishery species (including from illegal hunting and trade), and the spread of certain non-native invasive species. This loss of biodiversity affects livelihoods, water supply, food security, and lessens resilience to extreme events, particularly for people living in rural areas who are often the poorest.

## BIODIVERSITY IN ETHIOPIA

### Flora

Ethiopia, complex topography coupled with environmental heterogeneity offers suitable environments for a wide range of life-forms. The flora of Ethiopia is very heterogeneous and has endemic elements. The Semien and Bale Mountains have been identified as areas of plant endemism of continental importance. Their flora is diverse and the Afromontane representative show affinities to South African, Eurasian and Himalayan elements. The Southwestern broad-leaved evergreen forests show affinities to the Congolian forests of western Africa.

Vegetation types in Ethiopia are highly diverse ranging from afro-alpine to desert vegetation. It has a large number of plant species and a recent personal communication indicated that the number of higher plants described is 6021 species (Prof. Sebsebe Demissew) from which about 12% are probably endemic.

**Center of origin and/or crops diversity:** As a result, due to its geographical position and socio-economic diversity, numerous crop plants known to have originated elsewhere have developed an enormous secondary diversification in the Ethiopian region. Ethiopia is considered as one of the richest genetic resources centers in the world in terms of crop diversity ever since the expedition of the plant collector Vavilov in the 1920s. The country is known as one of twelve Vavilov centers of primary plant domestication in the world. Furthermore, crop plants such as coffee, safflower, *Carthamus tinctorius*, 'tef,' *Eragrostis tef*, 'noog', *Guizotia abyssinica*, 'anchote', *Coccinia abyssinica*, Ethiopian mustard, *Brassica carinata*, enset, *Ensete ventricosum* and coffee, *Coffea arabica* originated in Ethiopia. The country is also a center of diversity for species such as wheat (*Triticum* sp.), barley, *Hordeum vulgare*, sorghum, *Sorghum bicolor*, peas, *Pisum sativum*, cowpea, *Vigna unguiculata*, chickpea, *Cicer arietinum*, lentils, *Lens culinaris*, chat, *Catha edulis*, shiny-leaf buckthorn, *Rhamnus prinoides*, cotton, *Gossypium herbacieum*, castor bean, *Ricinus communis*, oats, *Avena abyssinica* and clover, *Trifolium* sp. Wild relatives also exist for most of these species known to have originated in Ethiopia. Local cultivars/farmers' varieties of several major crops like wheat, field pea, and faba bean, relatives of some of the world's important crops with enormous genetic diversity are abundant in the Ethiopian region.

### Fauna

Ethiopia has 284 species of wild mammals and 861 species of birds. Data on other wild animals are scanty; and the number of reptile species identified so far is 201, fish 200, amphibians 63 and arthropods 1,225. Of these animal resources, 29 wild mammals, 18 birds, 10 reptiles, 40 fish, 25 amphibians and 7 arthropod species are endemic to Ethiopia. The Ethiopian Biodiversity Institute (EBI) has done some limited research in the country, and various animal categories of terrestrial and aquatic origin were recorded, i.e., reptiles (78 spp.), amphibians (54 spp.) and fishes (101 spp.) out of which 3, 17, and 4, were endemic species, respectively (EBI, 2014). Moreover, domestic animal species that are known to have originated elsewhere (mainly in the so-called Fertile Crescent) comprised of 28 cattle breeds, 9 sheep, 8 goat, 7 camel, 6 donkey, 8 horse, 2 mule and 7 chicken (EBI, 2014) and these have developed their own center of secondary diversification. The Ethiopian hare is endemic to Ethiopia , and is found in the Afromontane Biozone of Ethiopia, and in the borders of the Sudanian Savanna Biozone; it also occurs west of the Rift Valley, in the Ethiopian Highlands, and abundantly found around the Lake Tana in Ethiopia (Happold, 2013).

The White-winged Flufftail (*Sarothrura ayresi*), a small, elusive, dove-sized rail endemic to Africa, has been uplisted to Critically Endangered on the IUCN Red List of Threatened Species. According to BirdLife International, the White-winged Flufftail population is undergoing a very rapid and continuing decline, with an estimated total population dropping to below 250 mature individuals. Although the bird's exact range and migratory behavior is still somewhat unclear, the bird is known to occur in Ethiopia and South Africa and there are limited records from Zimbabwe (AEWA. 2013).

## Microbes

Although there are no substantial studies on microbial resources, preliminary assessments demonstrate the existence of various types and species of microbes in the country. IBC directorate recorded about 800 microorganisms as of 2016. This diversity of biological resources is a clear demonstration of ecosystem diversity and biological wealth existing in the country. Thus, Ethiopia is also unquestionably a region for microbial diversity.

## Ecosystems

Ethiopia's boundaries encompass the major part of the eastern African highland massif. On the northern and western boundaries lie the foothills of the main massif. The Great Rift Valley divides the western and southeastern highlands, and the highlands on each side give way to vast, semi-arid lowland areas in the east and west, especially in the southern part of the country (EFAP, 1994).. The dry areas have isolated the highlands. Ethiopia is endowed with amazing geographic diversity with wide altitudinal and physiographic features ranging from 110 m below sea level at the Danakil Depression (Afar) to 4,533 m.a.s.l. on Mount Ras Dashen (Amhara) with mean annual rainfall ranging from 100 to 2400 mm (Friis *et al*., 2010). Besides, it harbors a significant portion of the Eastern Afromontane and Horn of Africa

Biodiversity Hotspots and one of the few East African countries that are considered the cradle of humankind (Hopkin, 2005; EWNHS, 2010).

Ethiopia is endowed with a variety of ecosystems (established but incomplete), the recognition of which is mainly based on the twelve vegetation types, and a glimpse of the 12 Ecosystems are: Afromontane Forest: 1. Desert and semi-desert scrubland (below 500 m.a.s.l.); 2. *Acacia-Commiphora* woodland and bushland (900-1900 m.a.s.l.); 3. Wooded grassland of the western Gambella region; 4. *Combretum-Terminalia* woodland and wooded grassland (500 to 1900 m.a.s.l); 5. Dry evergreen Afromonane forest and grassland complex (1500-2700 m.a.s.l); 6. Moist evergreen Afromontane forest (800 to 2,500 m.a.s.l.); 7. Transitional rain forest (450 to 800 m.a.s.l.); 8. Ericaceous belt (below 500 m.a.s.l.); 9. Afroalpine belt (The lower limit of the afroalpine belt falls at about 3500 m, while the upper limit of vascular plants lies around 5000 m); 10. Riverine vegetation; 11. Freshwater lakes, lake shores, marshes, swamps and floodplains vegetation; 12. Salt-water lakes, lake shores, salt marshes and pan vegetation and the Intermediate evergreen Afromontane Forest.

## Values of biodiversity

The diversity of organisms in an ecosystem provides essential food, medicines, and industrial materials. As many as 40 percent of modern pharmaceutical medicines in the developed world are derived from plants or animals. In Ethiopia, no less than 80 percent of the rural community and a significant proportion of the urban dwellers depend on herbal medicines for their primary health care delivery system. In addition to food, medicine, fuel wood, and construction materials, biological resources, especially forests provide wildlife habitat and recreational opportunities, prevent soil erosion and flooding, help provide clean air and water. Biological resources are also important biotic checks to pests and diseases and serve as defense line against global climate change.

## Threats to biological resources

As human populations increase and their encroachment on natural habitats expand, humans cause detrimental effects on the very ecosystems on which they depend. In the Ethiopian context, the most drastic damage has occurred in the natural high forests and their biological resources that have once covered more than 42 million ha (35% of total land area) of the land in the country. Unfortunately, human activities have greatly reduced biodiversity around the world. The greatest threat to teff (*Eragrostis tef*) biodiversity is loss of habitat as humans develop land for agriculture, grazing livestock, and unsustainable use such as draining wetlands and clear-cutting forests for agricultural land and polluting the air, soil, and water through unwise use of chemical compounds such as herbicides, insecticides, etc.

Main direct threats to Ethiopia's biodiversity are habitat conversion, unsustainable utilization of biodiversity resources, invasive species, replacement of local varieties and breeds, climate change, and pollution. Indirect causes of biodiversity loss in the country are demographic change, poverty, and lack of awareness and coordination. Thus, about 103 plant, 31 bird, 1 reptile, 9 amphibian, 2 fish and 14 other invertebrate species are threatened.

## CONCLUSION

As poverty reduction plan indicates, one of the key approaches is to help people involved to find ways to generate revenues from biodiversity—including through tourism or payments for environmental services—that can cover the cost of managing biodiversity and improving local economies. Biodiversity remains the answer to several sustainable development challenges. From nature-based solutions to climate, health issues, food and water security, and sustainable livelihoods, biodiversity is the foundation upon which we can build back better. The Secretariat of the Convention on Biological Diversity advances the slogan, "Building a shared future for all life".

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# Evaluation of the status of the Ethiopian nuclear infrastructure development

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**ABSTRACT**

Access to modern energy service is a development imperative. Ethiopia is rich in energy resources, but it has not sufficiently exploited them for its economic growth and as a result its socioeconomic development is not satisfactory. Its citizens are energy poor and don't have sufficient access to modern energy services. As part of its multi-layered activities in the Ten-Year Perspective Plan (TYPP 2021-2030), the current Ethiopian government, in addition to its renewable energy development plans has considered a nuclear power program (NPP) in its energy mix and desires to apply nuclear science and technology in its sustainable development strategies. The country is planning and preparing on infrastructure requirements for effective implementation of the national NPP. This review paper focuses on the role of nuclear science and technology in energy production and sustainable development, and evaluates the status of nuclear infrastructure development in the Ethiopian national nuclear program. The review discusses the main issues in a national nuclear program, nuclear energy management and nuclear knowledge management demands and strategies for its effective application. Knowledge-driven commitment to the nuclear science and technology program in developing countries like Ethiopia can boost economic growth.

**Keywords**: Nuclear Science and Technology; Nuclear Power Program; Nuclear Energy Management; Nuclear Infrastructure Development; Ethiopia

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## INTRODUCTION

Ethiopia is a country known for its natural resources and strategic geographical location. However, its socioeconomic development is not satisfactory. Its citizens are energy poor and don't have sufficient access to modern energy services (World Bank, 2022). Despite having various energy sources, including hydropower, wind, solar, geothermal energy and opportunity to harness nuclear energy, the country still struggles to provide basic electricity services to its citizens. More than 50% of the Ethiopian population does not have access to electricity and only 3% of the population has access to clean cooking. Access to modern energy service is a development imperative. The current government of Ethiopia has made several reforms in different sectors and aimed to facilitate

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investment in major infrastructure projects in key sectors (MoWIE, 2019; FDRE, 2020; FDRE, 2021) including the energy sector. In June 2019, the government of Ethiopia has ratified a nuclear and science and technology program with international support from Russia's government and the International Atomic Energy Agency (IAEA) to build nuclear infrastructure. The first of its kinds in Ethiopia, a national nuclear science and technology center with a nuclear research reactor and a nuclear power plant to benefit the use of Nuclear Science and Technology (NST) in electric, non-electric and non-power applications to different sectors in the economy are envisioned in Ethiopia's future. Girma Kibatu *et al*. (2022) have presented a review on NST as a part of Ethiopia's Energy Mix and Sustaianable Development Strategies.

The development of an effective and sustainable nuclear energy program requires the development of many critical infrastructures. The objective of this paper is to evaluate the status of nuclear infrastructure development in the Ethiopian national nuclear program. The main issues in the national nuclear program such as the issues of nuclear energy management and nuclear education/nuclear knowledge management demands and strategies for the effective applications of a nuclear program in Ethiopia are evaluated and recommendations have been suggested for successful development and implementation.

## ETHIOPIA'S SOCIO-ECONOMIC AND POLITICAL SITUATIONS

Ethiopia, a country with a population of 115 million, is the second populous country in Africa. The country has Africa's seventh largest economy by gross domestic products. Although Ethiopia is endowed with substantial land mass and natural resource potentials, its present socioeconomic condition is not satisfactory yet (World Bank, 2022). The country's economy has showed progress in the 1980s and 1990s relatively; however, economic development in Ethiopia has been beset with a continuing problem of balkanization and internal conflicts, lack of capacity in nation building, and political unrests due to lack of good governance. Thus, a new form of government has been formed in 2018. The current Ethiopian government has been learning from the development efforts in the 1980s and 1990s, and has redesigned a series of new policy measures to raise productivity in both private and public services including in the energy sector (MoWIE, 2019; FDRE, 2020). Ethiopians, therefore, once again, under the new leadership have hopes and good reasons to enter the 2020s into accelerated growth with social justice.

## Energy systems scenario in Ethiopia

Ethiopia has currently a final energy consumption of around 40,000 GWh, whereof 92% are consumed by domestic appliances, 4% by transport sector and 3% by industry. Most of the energy supply thereby is covered by bioenergy which in case of domestic use and imported oil and gas which is usually stemming from unsustainable sources (Yalew, 2022). Ethiopia is endowed with renewable and clean energy sources and has a potential to generate over 60,000 megawatts of electricity from hydroelectric, wind, solar, geothermal and nuclear power sources. However, the current total installed capacity of electric generation is approximately 4758.77 megawatts (2021) mainly generated by hydropower (90%) followed by wind energy (7.6%) and others (2.4%). Only 44% of the total population has access to electricity. More than 50% of the Ethiopian population does not have access to electricity and only 3% of the population has access to clean cooking. Currently, Ethiopia’s per capita electricity consumption of 100 kWh per year is the third-largest electricity access deficit in sub-Saharan Africa. The World Bank report in 2019 also indicates that the demand for electricity would double in a decade.

The current government of Ethiopia aims to achieve universal 100% access to electricity by 2030 and achieve Goal 7 of the United Nations Sustainable Development Goals, ensuring access to clean reliable and affordable energy for all. In the Ethiopia’s 25-year power system master plan (2022-2037), the aim is to generate up to 37,000 MW of power by the year 2037. Energy is essential for development and additional investment in the energy sector in addition to the Great Ethiopian Renaissance Dam project and other wind and geothermal projects on the pipeline is mandatory for growth. Much of the electrification available now is also highly dependent on a single energy source –the hydropower, which is unreliable and sensitive to climate change which, as a result, causes shift services and several outages (Mokonnen *et al*., 2002). Ethiopia therefore aims to achieve its vision through major scientific and technological projects in solar, wind, and geothermal and nuclear in addition to hydropower projects. As a part of this direction, Ethiopia has therefore shown interest to commence a nuclear program for the peaceful application of nuclear science and technology as one of the strategies to achieve its targets in both in its energy mix and sustainable development goals.

## Nuclear science and technology

Nuclear science, technology and innovation are multidisciplinary and highly specialized areas of science and technology that involves nuclear reactions of the atomic nuclei (Murogov *et al*., 2009). In addition to the kinetic energy and the heat from the reaction that is used for electrification, the radioisotopes (radionuclides), the neutrons (and or sub atomic particles) and the photons of gamma radiation produced in nuclear reactions have been harnessed in various applications. A notable example of a fission reaction of Uranium-235 by accelerated neutron as shown below shows results in a single nuclear reaction that can generate 200Mev energy.

***Brief history of nuclear science and technology***

The science of atomic radiation, nuclear change and nuclear fission was developed from 1895 to 1945, much of it in the last six of those years (World Nuclear Association, 2022). Over the years from 1895-1945 most development was focused on atomic bomb development. The years 1946-1956 were dedicated to the development of nuclear power plants for electrification. Today nuclear energy provides about 10.4% of the world's electricity from about more than 440 nuclear power reactors all over the world. South Africa remains the only African country to possess a nuclear power station. Many African countries including Ethiopia are preparing to be nuclear by 2030-2040. Since 1956 the prime focus of nuclear technology has been on technological evolution to smaller, safe and more flexible design and reliable nuclear power plants and recently much progress have also been made in non-electric and non-power application of nuclear science in other sectors other than electricity production which gave the technology a higher demand in the next decades.

***Applications of nuclear science and technology***

In the course of developing nuclear weapons, nuclear scientists and technologists had acquired a range of new power and non-power nuclear technology applications for peaceful purposes. Applications of nuclear science and technologies in nuclear energy for electric and non-electric applications, and in non-power applications in food and agriculture, health and medicine, manufacturing and industry, water resource management and sustainable environment management play significant role in driving socioeconomic and sustainable growth of a society (Walter, 2003). Application of nuclear energy in electrification is seen in below (Figure 1).

## THE ETHIOPIAN NUCLEAR POWER PROGRAM

### Nuclear science and technology in Ethiopia

The application of nuclear techniques in Ethiopia started in the early sixties in the medical field and has gradually expanded to other areas such as agriculture, animal health and research, hydrology, mining and industry. Applications of nuclear energy are not known in Ethiopia. Ethiopia has only one public nuclear medicine center and one radiotherapy center at Black Lion Specialized Hospital in Addis Ababa for the whole country (Demena, 2002).

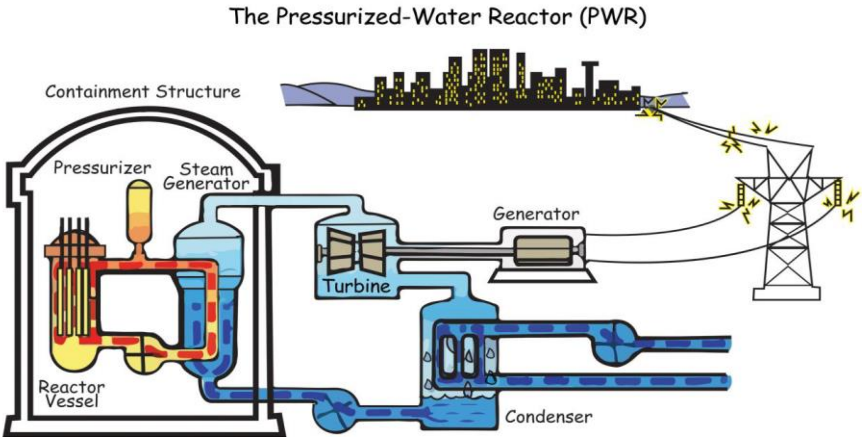

Figure 1. Typical nuclear power plant

The government has plans to expand these services in regional hospitals. The tsetse fly eradication project using radiation technology in the Rift Valley, and plant breeding project using radiological methods to improve teff varieties in Debere Ziet are other main endeavors in the Ethiopian national agricultural research centers (Alemu *et al*., 2007). Nuclear measuring and detecting devices have also been used for gauging in different beverage, construction, transport industries and customs services.

## Uranium geology exploration and resources in Ethiopia

Ethiopia has prospective geology with mining potentials for certain minerals (Assefa *et al*., 1991; Oluma, 2009). In a report from an old Newspaper *New York Times* on May 15, 1954 it was mentioned that Emperor Haile Selassie I has announced that some of the best uranium ore in the world had been discovered in Ethiopia (New York Times, May 15, 1954). This was even before the formation of the IAEA where the world also knew little about the nuclear technology. An outcome of a recent two-year survey in 2019/20 on the prospect for mineral resources across Ethiopia, identified uranium among several other minerals in six weredas/districts of the eastern region, including Harar, Kersa, Babile, Girawa, Midaga, and Faddis (Geological Survey of Ethiopia, Ministry of mines and energy, 2021). However, results of this work have not been published or verified and therefore further research is needed by providing technical assistance to help the survey of Uranium mines in Ethiopia, to get a better idea of how much uranium ore in Ethiopia is economically feasible.

## Nuclear knowledge management in Ethiopia

The Ethiopian education and training system and research activities provides little or no base for NST. There are only a few nuclear education and training programs in the education system in Ethiopia (Belete, 2004). Physical components like facilities and training and research institutions are at their primary level. Less emphasis is given for nuclear education at high school and undergraduate studies in sciences or engineering. Only some universities in Ethiopia are running MSc programs in nuclear and radiation physics. Addis Ababa University has a PhD program in nuclear physics and specialty degrees in radiology and nuclear medicine. Addis Ababa Science and Technology University has recently established a center for Nuclear Reactor Technology, an MSc program in Nuclear Science and Engineering and is planning to build capacity in the field. There are otherwise no typical universities running nuclear and radiological sciences, nuclear engineering or technology and radiopharmaceutical programs in the country.

Following the need assessment and lack of human resources in the field of nuclear science and technology, developments of educational programs and curriculum development activities in Bahir Dar University to integrate nuclear education in its education base has been started. A joint new MSc in Nuclear Science and Engineering program based on best practices on nuclear knowledge management and education has been proposed and approved by the university where faculty (Figure 2) from the college of Science and the Institute of Technology join to manage the program in Bahir Dar. Despite the recent few developments in the national education system and education base for nuclear science and technology in the country, specific policy and regulation for standardization and modularization does not exist.

## The status and development of nuclear program in Ethiopia

Ethiopia's National Nuclear Program has two parts. The first phase of the country's nuclear program aims to set up a National Center for Nuclear Science and Technology with Nuclear Research Reactor and other facilities for comprehensive services in non-electric applications and training and research needs by 2024.

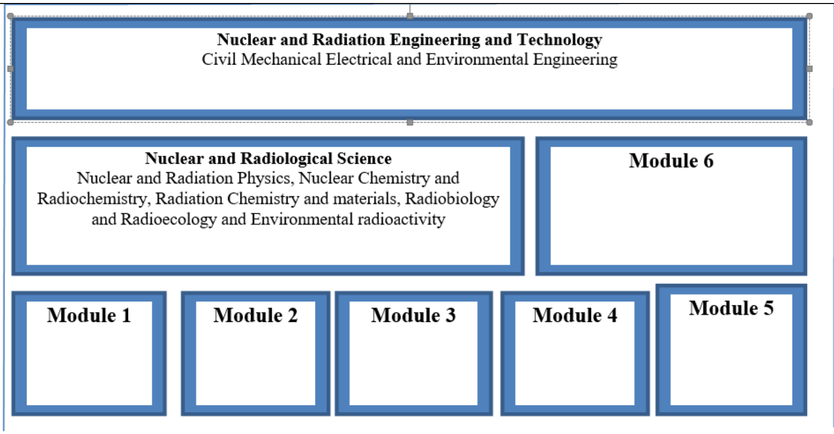


Figure 2. A schematic program structure for proposed curriculum for an MSc in Nuclear Science and Engineering; Module 1 Nuclear and Radiation Physics; Module 2 Nuclear Chemistry and Materials; Module 3 Nuclear Power Technology; Module 4 Nuclear Technology in Non-Power applications; Module 5 Nuclear Safety Security and safeguard'; Module 6 Mathematics Computer science and Social sciences/Humanities and arts (Kibatu *et al*., 2022).

The second part of the country's nuclear program is a Nuclear Energy Program to introduce nuclear energy into Ethiopia's energy mix. The country is currently considering both large and small modular reactors for its nuclear energy. The country is currently considering implementing large research reactor program in a national center for nuclear science and technology in the near future and has set a target of 2035-2040 to have its first nuclear power plant up and running.

***The IAEA milestones approach***

The International Atomic Energy Agency (IAEA) has developed an internationally accepted method to implement sustainable nuclear power programs for newcomer countries considering launching a nuclear power program in their development (IAEA, 2015) (Figure 3).

***Nuclear energy management***

Three key organizations are involved in building a nuclear power program (IAEA, 2006). The government should create these three organization structures as a mechanism to coordinate, regulate and operate. For example, a Nuclear Energy Program Implementing Organization (NEPIO) devoted to coordinate the work of all organizations involved, a competent, independent regulatory body must be developed to ensure it that it combines with all nuclear safety standards. The Owner/Operator may be state owned or private and must be competent to safely operate the nuclear power plant and meet regulatory requirements.

***Nuclear infrastructure development***

The International Atomic Energy Agency (IAEA, 2008) provides member states embarking into a nuclear program an opportunity and a methodology to evaluate the status of their national ***nuclear*** infrastructure on the basis of the Milestones Approach and associated 19 infrastructure issues (Figure 4). The evaluation methodology used is documented in the IAEA publication *Evaluation of the Status of National Nuclear Infrastructure Development, IAEA Nuclear Energy Series No.NG-T-3.2 (Rev. 1), IAEA, Vienna, (2016)*. The methodology provides a comprehensive assessment of all facets of a nuclear power program to ensure that the infrastructure required for the safe, secure and sustainable use of nuclear power is developed and implemented in a responsible and orderly manner. Recommendations and suggestions to the Member State can be obtained from this assessment to support the development of a national action plan to identify the gaps and address the gaps identified.

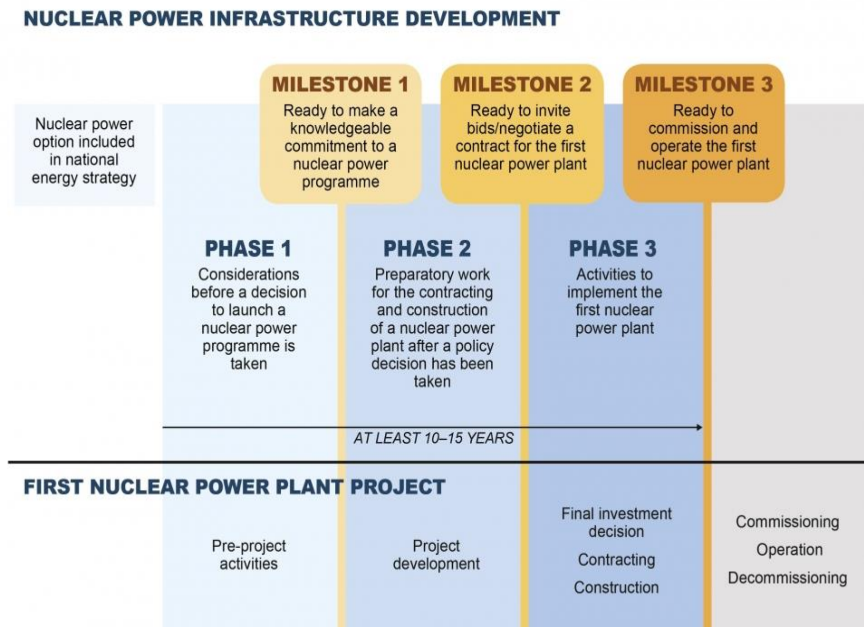


Figure 3. Phases of infrastructure development for nuclear power

Figure 4. Infrastructure issues

## Evaluation of status and development of nuclear program in Ethiopia

Two agencies; a Nuclear Energy programme Implementation unit (NEPIO/National Nuclear Science and Technology Task Force) in the ministry of innovation and technology as a promoter, planner and organizer to the national nuclear program and an Ethiopian Technology Authority as a regulatory body are now guiding and working on regulating services pertaining to the national nuclear program of Ethiopia. The new Nuclear and Radiation protection (Technology Authority) Proclamation (Proclamation No. 1025/2017) includes provisions on regulating nuclear infrastructures and radioactive waste management. The Ministry of Water, Irrigation and Energy directs the energy situation in the country. State-owned companies own and operate energy infrastructures in the country. However, plans on who owns or operates future nuclear power plants to be established are not yet decided. The Ethiopian Nuclear Program also enjoys bipartisan support from technology providers.

The national policies such as the TYPP, the National Energy Policy, the National Strategy of Climate Resilient Green Economy, SIT policy, and the National Energy Master Plan for Ethiopia (EFDRE, 2020-2021) all provide an overall framework and base to justify the need for the implementation of a nuclear program. These policies have been taken as a policy base to strengthen the legal, institutional, and operational framework of nuclear science and technology in the country. Key government decisions have been made based on policies and recommendations from the NEPIO, the national regulatory body, the technology vendor and the international atomic energy agency. With this guidance the government of Ethiopia has taken both the cabinet and the parliament to decisions to introduce a national nuclear program in 2021. However, Ethiopia has not yet drafted an independent national nuclear policy. Ethiopia's decision to embark into the nuclear program, however, has not been supported by strong policy justification strategic documents and missions (a National Nuclear Policy, Pre-feasibility study for a national nuclear program, a national Nuclear power roadmap, a nuclear programme implementation plan, request for information issued to seek both technical, financial and contractual information from the vendor countries regarding the technology they intend to deploy to Ethiopia and other issues remains to be completed before stronger decision to go on). These endeavors are either under consideration or yet to be produced for a strong policy justification and commitment from all stakeholders involved in the project.

The evaluation of the status of the Ethiopian Nuclear Program using the IAEA's milestone approach, and considerations to the timeline shows that Ethiopia is now in pre-project activities in phase I. The country has already made some preparations to include nuclear power in its future energy mix. The Ethiopian national power program is still at the end of its phase I stage and is prior to achieving the 1$^{st}$ milestone. Accordingly meta-activities including 1) Developing pre-feasibility studies, policies and strategies; 2) Developing legal and regulatory framework; 3) Conducting site related activities and 4) Developing and maintaining organizational structures are activities that have to be completed before the *Integrated Nuclear Infrastructure Review* (INIR) Phase I mission for Ethiopia to reach into its 1$^{st}$ milestone in the development of the nuclear Program. The country currently is undergoing working on strategic plan, feasibility study, and potential site selection and is also in parallel planning for the development of other infrastructures needed for an effective nuclear program and may hit the 1$^{st}$ milestone probably at the end of 2023.

## Concerns/challenges on the national idea on nuclear power program

Newcomer countries like Ethiopia embarking into a new nuclear energy power programs with little experience in the science and technology usually face some concerns to implement an effective, affordable, and large sustainable development project in the energy sector. Some of the important issues, concerns and challenges raised in building national nuclear program are included in the following list: National position and capacity building; Finances and funding schemes; Human resource development; Nuclear energy management; Legislative and regulatory framework; National electrical grid;

Accidents and security threats; Radioactive waste and limited fuel supply; and Public opinion and awareness (Adams and Odonkor, 2021). The evaluation of the status of these challenges, techno economic analysis for the construction and operation of nuclear power plants and concerns in the Ethiopian Nuclear Program, based on the international practice and guidelines for the development of a nuclear program for embarking countries, show gloomy situations (Ayalew, 2021; Wondimagegn, 2022). As nuclear technology is highly regulated, Ethiopia also needs to develop robust infrastructures *(such as Atomic Energy Commission; Nuclear Power Authority; Nuclear and Radiation Protection Authority; Nuclear and Radio waste Management Agency and organization for Nuclear Security*) in the national nuclear program. The success of the program is highly dependent on how these challenges and issues are addressed properly on time.

## CONCLUSIONS AND RECOMMENDATIONS

This review shows why the peaceful use of nuclear science and technology makes sense in an Ethiopian context. Socio-economic and environmental considerations show that the use of nuclear and radiation technologies in the energy-mix and to accelerate sustainable development in Ethiopia are essential. The Ethiopian national power program is in pre **project** activities, at the end of its phase I stage prior to achieving the $1^{st}$ milestone. The mix of energy supply in Ethiopia is as important as energy supply in low-income countries striving for sustainable development. Renewable energy sources such as hydropower, solar, wind and geothermal energy developments coupled with nuclear based energy development provide a future gateway for sustainable economic transformation through industrialization, urbanization as well as through the provision of access to modern and clean energy to all sectors in society. In addition to the provision of modern and clean energy, non-electric and non-power peaceful applications of the nuclear science and technology in many sectors such as health, agriculture and industry help Ethiopia to achieve its sustainable development goals.

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# Status of natural product sciences in Ethiopia

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**ABSTRACT**

This brief review summarizes important episodes in the plant chemistry research undertaken over two centuries from and within Ethiopia. Ethiopia is endowed with a substantial plant and animal genetic resources, some of which were tapped for food or medicine throughout the generations, albeit traditionally. In order to fully realize the benefits of these resources, their chemical contents need to be investigated with state-of-the-art chemical analysis. Chemistry's vital role to do this was greatly facilitated by the opening of graduate programs in Addis Ababa University, and later in other universities, which led to a steady stream of research undertaken mostly on native plants that were expected to have some potency as medicine or food additives. These include among others, coffee, *khat, khoso, endod,* civetone, *mettere, kebericho, gesho,* etc. The challenge with regard to using natural products is the miniscule amounts of the active ingredients, which will not allow the full range of evaluations in terms of benefits, toxicity, etc. to be done before application. Genome editing and synthetic biology are expected to enhance the production of these active compounds in the near future.

**Keywords:** Organic chemistry; Ethiopian medicinal plants; Indigenous knowledge; Biological products chemical analysis; Active ingredients

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## INTRODUCTION

The first Department of Chemistry in Ethiopia was within Addis Ababa University and as a full-fledged academic department it graduated only one student in its first batch 55 years ago in 1968. I was in the second batch of 16 students who received the BSc in chemistry a year later. I did my senior research project on the psychoactive plant *Catha edulis* Forsk (known as ጫት). I isolated a simple ephedrine alkaloid but although this finding may not have been great; symbolically the exercise I did, supervised by R.O. Whipple may very well have been the beginning of natural products chemistry research in Ethiopia. *Chat* is a well-known plant and is widely used in Ethiopia, initially among the Muslim communities, but is now used all over. The UN sponsored a study on chat and concluded that it should be classified as a narcotic. Although as many as sixty

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or so alkaloids, terpenes, flavonoids and tannins have been found the psychoactive principles are believed to be simple phenyl alkyl amines particularly the unstable cathinone and to a lesser effect cathine (Wabe, 2011).

## HISTORICAL BEGINNINGS OF NATURAL PRODUCTS SCIENCE FROM ETHIOPIAN SOURCES

One of the earliest records of structural elucidation of natural products from Ethiopian sources may be associated with the constituents of the stimulant plant *Coffea arabica* (Rubiaceae). Caffeine was first isolated as a white crystalline substance in 1819 by a German scientist, Friedlieb Ferdinand Runge (1820). But it was the Nobel laureate (1902) Emil Fischer of the University of Erlangen, Germany who studied the active principles of tea, coffee and cocoa, namely, caffeine and theobromine, and established the constitution of a series of compounds in this field, eventually synthesizing them. Caffeine is a stimulant found principally in coffee, tea and the cola nut, but it is known to occur in the seeds, nuts and leaves of as many as 60 other plant species or varieties. Although coffee is traded among all nations of the world, it is produced only by a few countries in Africa, South America, and Asia. The origin of coffee, *Coffea arabica*, is believed to be in the Kaffa region of Ethiopia, the only place in the world where the coffee plant is found growing in the wild. Coffee is consumed primarily for two reasons: to overcome drowsiness and be alert as well as to improve physical performance. Traditionally, coffee is a socializing process particularly in Wollo region where they drink the first coffee extract (አቦል), then the second (ቶና) and finally the third extract (በረካ). Caffeine has an additional use in medicine to assist infants with respiration. Caffeine has a chemical structure with striking resemblance to adenine and guanine, which are components of DNA. Caffeine has a remarkable solubility in both water (hot) as well as non-polar media and hence the ease with which it crosses the lipid barrier to get to the brain. Its stimulant properties are a result of its ability to reversibly block the action of adenosine by binding on its receptors. Coffee is also regarded as a diuretic, but this is probably due to the theobromine which is a metabolic product of caffeine and thus is present in the body arising from the caffeine that is consumed.

A second plant of significant history going back over 200 years is *Hagenia abyssinica* Gmel, a plant (ኮሶ in Amharic) whose female flower-extract was widely (and may still be) used as a taenicide in Ethiopia. There was a time when Europe was plagued with this parasite and the story goes that a physician (Brayer) was at a barber's shop in Constantinople (ca 1820). Once you sit on a barber's chair you are a victim listener and Dr. Brayer heard of the miraculous taenicidal effects of the Ethiopian plant which may be obtained by chance encounter with travelers passing along the Red Sea who then took it to Europe for its medicinal uses. The doctor even managed to get a sample from his barber whom he took and administered to a lady who had taenia and meticulously recorded her heart beat, blood pressure, temperature, etc., thereby documenting the first effects of a patient treated with *Hagenia abyssinica*. The doctor was happy with the results of the medication and took two important actions. The first was to show the flowers to a botanist (Kunth) who identified it as belonging to the family Rosaceae and called it *Brayera antihelimintica* Kunth; and secondly, he presented a paper at the French Society meeting of 1820. There is a lot of history written about the Kosso plant and significantly in 1874 the German company Merck marketed the structurally unidentified white substance called "kosins" as an anthelmintic (Fluckiger and Buri, 1874). The chemical structure of kossotixin was published a century later (1974) by a Finnish chemist (Lounasmaa *et al*., 1973). Previously, famous chemists like Birch and Todd (1952) failed in their attempt to elucidate the structure of the active ingredient.

There is no taenicidal drug in the market derived from an Ethiopian plant at the present time although there are many plants that are sold in the traditional market for use against tapeworm infestation. A former colleague in our faculty who was a traditional doctor once revealed to us that there are as many as 147 plants in Ethiopia which he knows to be taenicidal. Our natural product scientists should be disappointed for this failure to have a drug in the market and this may be an important topic for the leaders including policy makers to investigate the reasons and seek corrective measures for the future.

The third example of a natural product is of animal origin called civetone which was identified by Leopold Ruzicka (Ruzicka, 1926), a Czech chemist who worked on civet material that was exported from Ethiopia to London and then shipped to him in Czechoslovakia. He elucidated the structure of civetone as a 17 carbon -ring macrocyclic ketone. Ruzicka got the Nobel Prize for chemistry in 1939. Large carbocyclic rings were not known at the time, and curiously were thought unlikely to exist. In the first Peeler Lecture delivered before the Chemical Society in London in 1929, W.H. Perkin Jr. I described "the early history of the synthesis of closed carbon chains". He dealt not only with the reactions which led to the synthesis of small carbon rings during the period 1881-1883, but also with the pessimistic views of the leading chemists of that time regarding the possible existence of carbocycles other than the 5- and 6-membered rings. Adolf von Baeyer, Emil Fischer, and Viktor Meyer advised Perkin not to waste his time on attempts to prepare such compounds, which could hardly be capable of existence. Civetone is highly valued as a component of expensive perfumes and is attributed with fixative values of the sensual and erotic constituents of the perfumes.

A fourth example and one that involved an Ethiopian scientist is *Phytolaca dodecandra* or otherwise known as *endod* እንዶድ in Amharic or soapberry in

English. An Ethiopian scientist - Aklilu Lemma - discovered that Endod possessed molluscicidal properties by noticing a lot of dead snails along the banks of the Adwa River where people used the berries of the plant for washing their clothes. Endod was shown to reduce the incidence of Bilharziasis in a field study conducted in Adwa, Tigrai (Lemma, 1990). Aklilu was interested to know the active ingredients of this plant and work conducted in California revealed that saponins were responsible for the biological activities of the plant (Parkhurst *et al*., 1974). It is a pity that Aklilu did not reach out to compatriot chemists to elucidate the structures of the endod active principles. But in all honesty, the facilities in Ethiopia were not as developed as they are now and it is understandable that he preferred quick results that scientists in California were able to deliver.

## MODERN NATURAL PRODUCT SCIENCE FROM ETHIOPIAN SOURCES

About half a dozen of the best and the brightest graduates of the first two batches from the Department were sent for graduate education in the UK and the US. Most of these students returned to the country in 1972 and 73 and constituted themselves as a group to develop a chemistry program of training and research in the country. The first publication based on work conducted, partly in Addis and partly in Ibadan (Nigeria) was the structure elucidation of a bidesmosidic saponin from the Ethiopian medicinal plant *Glinus lotoides* (ሙቱሬ) (Abegaz and Tecle, 1980). Work in natural products by Ethiopian scientists began since then and continues until today. It must be recognized that the progress in the science of natural products was heavily facilitated by the previous publications on traditional medicinal uses of plants in Ethiopia and the SAREC supported project to write the Flora of Ethiopia. One of the earliest papers (Baxter, 1987) published in Volume 1 of the *Bulletin of the Chemical Society of Ethiopia* is entitled: Some thoughts on traditional Ethiopian chemistry. In this article Bob Baxter reflected on the subject and began his article by saying: The story of indigenous Ethiopian Science and technology remains to be written. It appears however, Ethiopian Scholars of the past were men of letters, chiefly interested in such matters as poetry, history, theology, law and magic and frequently displayed much depth and ingenuity in their discussions of these topics. Robert M. Baxter was a Canadian biochemist and the 2nd head of the Department of Chemistry of the then Haile Selassie I University from 1961-1973. Baxter considered our decision to launch this first journal of chemistry and remarked: the establishment of the *Bulletin of the Chemical Society of Ethiopia* can be thought of as marking the emergence of a distinct and productive Ethiopian community within the framework of world science. It seems that Baxter was right in recognizing the advent of the appearance of a series of papers on natural products that came from the dissertation research of postgraduate students in the Department of Chemistry, the School of Pharmacy and subsequently from the many higher education establishments that were established in various administrative regions of the country. Many highly prominent medicinal plants that have been used culturally in the country were investigated and hundreds of papers published in peer reviewed journals. Some of the highly popular medicinal plants addressed in this period include *Echniops kebericho* Mesfin (Compositae) (Abegaz *et al*., 1991), *Taverneria abyssinica* ድንገተኛ (Duddeck *et al*., 1987), *Rumex abyssinicus* (Fasil *et al*., 1985), *Kniphofia foliosa* (የጅብ ሺንኩርት) (Dagne and Steglich, 1984) and many more.

Another culturally important plant is *Rhamnus prinoides* or otherwise known in Amharic as *Gesho* (ጌሾ). MSc student Teshome Kebede studied this plant and identified several secondary metabolites. But perhaps the most interesting result was the identification of the bitter principle of the leaves and stems of the plant which turned out to be a new natural product called Geshoidin (Abegaz and Kebede, 1995). An informal panel was set up to taste an aqueous solution of Geshoidin and concluded that the characteristic taste of *tella* was in the aqueous solution of the glycoside. The gesho plant produces abundant quantities of this substance and can be considered as a viable source should it be needed in large quantities. Gesho is an important ingredient in the locally brewed domestic beverages of *tella* and *tej*. The plant is known to occur in many countries from Ethiopia to South Africa, but it is only in Ethiopia where it has been domesticated, cultivated and sold in traditional markets. Two areas famous for the production and cultivation of Gesho are the Kara Kore area in northern Shoa and also in Tigrai region. A recent study to determine the acute and sub-acute toxicity of the leaves on rats resulted in no significant damage to various organs (Abebe, 2023). Hence it is important to know that gesho leaves do not have any toxicity to worry about.

## WHAT BROUGHT ABOUT THE GROWTH AND DEVELOPMENT OF NATURAL PRODUCTS IN ETHIOPIA?

The most critical contribution in any endeavor comes from knowledgeable and skilled people. But the growth and development of natural products in Ethiopia was due to a multitude of factors and an effort will be made here to include the important ones. These include people at various levels in terms of not only the scientists to undertake the work but also the institutions that promoted and allowed such work to be undertaken; those in policy that endorsed and supported the project including funding it. Much of the work was done in the process of teaching postgraduate studies as dissertation research for the students. Chemistry is a molecular science and requires the availability of sophisticated instrumentation which is very expensive and demands special supplies and highly skilled technicians. Cryogenic liquids such as liquid helium, nitrogen and inert gases require special arrangements to acquire.

In the early 70s, the New Science Complex was constructed using a loan from the World Bank long before decisions were made in the university to initiate graduate programs. The loan also had provisions to acquire equipment for the center. The briefing given to the committee to plan for what was to be the new science center did not make any reference to a future graduate program that the center would be likely to house. The author of this paper was a member of this committee and it was his personal vision that sooner or later there would be graduate programs and he felt that facilities for such should be included. But there was no evidence to indicate if this was a view held by all committee members across all disciplines. So, for chemistry items like NMR, MS, etc. were included. In the late 70s, some graduate programs were initiated- during a decade that also saw the great Ethiopian famine, the downfall of the Haile Selassie I Regime, the bitter Ethiopia war against the Somali expansionist regime and the ascent to power of young military officers with socialist leanings. The prevailing attitude with the hunger, responding to the needs of the proletariat did not make vertical expansion of the higher education a priority at the time. The author clearly remembers the fear in the minds of Addis Ababa University authorities who were convinced that the Government would not approve the launching of postgraduate studies especially if the funds for it were to be requested from internal sources. As a result, they were happy to state that the proposal to launch postgraduate education would not require the allocation of significant resources. So, we forged ahead with MS programs in the 70s and PhD programs in the 80s. Luckily, the Swedish SAREC supported the postgraduate program and every dissertation and thesis had to express gratitude to Sweden for financial support to the graduate program. It was at this time that the concept of the sandwich program was launched. Post graduate students were able to travel to countries like Sweden and Germany to get access to better instrumentation and literature to be able to compose scholarly writings. Hence the graduate program was developed in an atmosphere of scarcity. Deeper knowledge was acquired through the graduate research programs but interdisciplinary knowledge and skills were minimal. Papers were published but patents and efforts to develop products and services were more or less avoided. So, it is possible to conclude that we were able to explore the chemistry of natural products and also get a little bit of understanding and appreciation of the culture of traditional medicine. But very little effort was done successfully to either develop any products or services.

## THE FUTURE OF NATURAL PRODUCTS RESEARCH, CHALLENGES AND SOLUTIONS

There is no doubt that the success of natural products research must be judged by the benefits that accrue to the population. One of the aspects to consider in natural products work especially in linking the ingredients to benefits is the quantity of the desired substance in the source plants. If the active substance is in microgram or milligram amounts then not much testing can be done. Bulk plant materials are sometimes not feasible to isolate large quantities if the extraction and purification protocols are complex. Though rare, some natural products are present in abundance while the generally accepted norm is that others are present only in minute quantities. For example, dehydrocostus lactone is a sesquiterpenoid natural product that is found in abundance in ቀበርቾ (*Echinops kebericho* Mesfin). Likewise, Geshoidin can also be isolated in large quantities from the stems and leaves of ጌሾ (*Rhamnus prinoides*), and the oil of *Carum copticum* is almost technically pure carvacrol. The three plants mentioned above give good quantities of natural products and of these; carvacrol is the only one that is commercially produced from plant sources such as oregano (*Origanum vulgare*), thyme (*Thymus vulgaris*), pepperwort (*Lepidium flavum*), and wild bergamot (*Citrus aurantium* Bergamia). Carvacrol is effective against food-borne pathogens, including *Escherichia coli*, *Salmonella*, and *Bacillus cereus*. It is not possible to make any conclusions regarding the clinical importance of carvacrol because of the absence of human trials.

One of the most outstanding examples of natural products from natural sources is the antimalarial compound artemisnin isolated from the Chinese medicinal plant *Artemisia annua*. This plant has been used to treat malaria in Chinese traditional practice for hundreds of years. Today the WHO recommended treatment for malaria is Artemisia Combination Therapy called ACT. This guideline is intended to avoid the emergence of resistant parasites to the drug. A major global concern has been to meet the global demand for the supply of artemisnin for treatment of malaria. The 2015 Nobel Prize in physiology and medicine was awarded to a Chinese scientist, Youyou Tu, for her work on the plant *Artemesia annua*, sweet wormwood, and showing substantial inhibition of rodent malaria parasites (Liu *et al*., 2016). Although the effect of this substance in curing patients was spectacular it was realized that neither the plant nor the results of chemical synthesis would be able to meet the global demand for the natural product. But recent advances in recombinant DNA technology (Khan *et al*., 2016) and synthetic biology (Martin *et al*., 2003; Voigt, 2020; Song *et al*., 2021)) have provided possibilities to get bacteria to produce sufficient quantities of artemisnin. For example, Song *et al*. (2021) were able to establish in *Bacillus subtilis* a CRISPR-Cas9 system that enabled them to do precise and efficient genome editing. This led to a strain which increased extracellular amorphadiene production from 81 to 116 mg/L after 48 h flask fermentation without optimization (Song *et al*., 2021). A recent article by Chris Voigt (Voigt, 2020) states: Products from synthetic biology are rapidly permeating society and by 2030, it is highly likely that you will have eaten, worn, used or been treated with one (Martin *et al*., 2003). Amorphadiene is a known precursor of artemisnin and can be synthetically converted to the target molecule in four steps. The lesson to learn from this paragraph is the need to embrace genomics and genome editing as a path to maximizing the benefits of natural products to society.

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# Science and technology higher education in Ethiopia

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**ABSTRACT**

This paper is an attempt to summarize the history of higher education in Ethiopia. Literature was not available equally for all science fields the author searched in the brief time he had; some were adequately represented while others were not. This work therefore represents what was available online at present. Here we define science as natural, engineering, medical, agriculture, etc. Higher education in general has started in the mid- 1950s and progressively widened its scope and geographic area coverage in the country. This article briefly highlights the beginnings of higher education, policy shifts, administration, financing, research attempts and challenges faced over the years.

**Keywords**: Education; Higher learning institutions; Policy; Science; Development; Ethiopia
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## EDUCATION IN ETHIOPIA

The history of secular education in Ethiopia is only about 100 years (Sbhatu, 2021). The regimes of the 20th century Ethiopia had their own peculiar secular education systems and each of them left the scene with challenges of their own creation and inherited ones. Primary and secondary education systems varied with regimes and had problems of policy, curriculum practicality and inappropriate temporal and spatial alignment.

### The beginnings of higher education institutions (HEI)

Modern higher education in Ethiopian has begun in the mid-twentieth century (Boateng, 2020). In July 1950, Emperor Haile Selassie managed to get the help of Jesuit Canadian teachers in establishing a college, the University College of Addis Ababa (later AAU). The college was established to prepare students for further overseas study or vocational certificate education (Lulat, 2005). Then six other specialized technical colleges had been established in the 1970s in addition to AAU, which was then followed by the establishment of Haramaya College in 1953 (Girma, 1967). They were all modeled more American than the former British East African colonies.

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## The recent higher education policy

A few years ago, the then Ethiopian government was desirous to become a middle income nation by 2025 and transform agriculture based economy to industry and services (Salmi and Sursock, 2017). The backbone of this transformation was infrastructures such as roads, railways, energy, and telecommunications. Also, a climate-resilient green economy, renewable energy projects, industry, and construction were identified during the second Growth and Transformation Plan (GTP II). It included mining, chemicals, petrochemicals, pharmaceuticals, construction, transport, information and communication technology, and agro-processing industries.

New industrial parks were built and hydropower dams were under construction to meet local energy demand and for export. All these developments required middle- and highly-skilled workforce and the education system had to respond to these demands (Salmi and Sursock, 2017).

The higher education system meets these demands through high-quality graduates, especially in science and technology, problem solving research, and closer links between universities and industries. The GTP II underpins the need for enhanced national research and technology capacity of the country. According to the five-year plan, higher education was believed to enhance competitiveness and growth. For this to materialize, establishing centres of excellence were high in the agenda. The Education Sector Development Program V for 2015/16–2019/20 (ESDP V) and the National Science, Technology, and Innovation (STI) Policy, were in place to implement this agenda.

Higher learning institutions supply not only demand-driven, professionally competent, skilled and attitudinally mature graduates, but they also supply relevant and client/problem oriented technologies via innovative and adaptive research, and contribute to the realization of the national vision of a middle income economy by 2025 (Bechere *et al*., 2015). Successive five-year education sector development plans (ESDP) have been implemented, i.e., ESDP I, ESDP II, ESDP III and ESDP IV (coinciding with GTP I).

With the GTP in action, the Science Technology and Innovation policy identified 17 sectors in which universities are urged to establish partnerships with industries in their respective domains. The first four successive ESDPs were criticized for inadequate reviews during annual education development planning. The culture of strategic thinking and long-term planning was practiced during the first GTP. ESDP V tactical plan and the education sector GTP II for the five year period from 2015/16 was to consolidate existing universities and establish 11 new ones, improve equity, relevance and quality of tertiary education, strengthen research and technology transfer, and institutional leadership, collaboration and internationalization. Also, leadership, good governance, and performance improvement tools, such as the Business Process Re-engineering, Balanced Score Card, Kaizen and the Education Development Army were attempted in the higher education institutions.

The Government viewed higher education and Science Technology and Innovation as the engines of economic growth and it soon enacted Higher Education Proclamation No. 650 in 2009. The proclamation gives direction to expand higher education, provides legal framework to ensure relevance and quality of education and research, provides bylaws and system of governance, etc. (FDRE, 2009).

## Education Roadmap

In order to draw the roadmap for the future, a desk review and field work exercise were conducted geared towards the implementation of higher education in Ethiopia. Seven thematic areas, i.e., access, equity, unity with diversity, quality, relevance, efficiency, and financing of higher education were used as indicators during the study (Teferra *et al*., 2018).

The findings show that higher education has expanded rapidly in terms of facilities, human resources, enrolment rate (10.2% in 2015/17), and graduation rate. However, gender gap in enrolment among male and female persists and most universities are confronted with insufficient supplies of text and reference books, laboratory and workshops equipment, and access to ICT facilities. To reach a middle-income category in 2025, Ethiopia had to achieve at least 22% gross enrolment, but the available resources and modalities of financing do not allow reaching 22% gross enrolment by 2025.

## University-level Agricultural Education in Ethiopia

Higher education in agriculture goes back in time to the mid-1950s. An agreement between ‘Point Four’ of the United States of America and Ethiopia on June 16, 1951 heralded the beginning of higher education in agriculture in Ethiopia (Belay, 2010).
Further, the agreement for a Co-operative Agricultural Education programme between the Imperial Ethiopian Government and the Government of the United States of America was signed in Addis Ababa on the $15^{th}$ of May 1952, laying down the foundations for the establishment of Jimma Agricultural and Technical School and Alemaya College of Agriculture, now Haramaya University (Belay, 2010). Subsequent agreements gave Oklahoma State University, USA, the mandate to establish and operate the College including nationwide agricultural extension, research, and its administration. The Emperor chose Alemaya, 525 km to the East of

Addis Ababa, for this project. A land-grant College system was adopted with three purposes, i.e., training, research and extension. On the other hand, Jimma Agricultural and Technical School was opened on June 24, 1952 in Jimma, south-western Ethiopia, with the objective of training students in modern agricultural practices and solve the shortage of mid-level qualified manpower in Ethiopia. In Jimma, the first batch of 80 students (chosen from 500 applicants) started class in October 1952 and 19 of them graduated on 6 August 1953 and remained in Jimma to become the first freshman students there. The first university-level agricultural training program, with a 4-year curriculum leading to a BSc degree in General Agriculture, started in September 1953 in Jimma. And 11 of 19 students graduated with a BSc degree in July 1957. The curriculum of general agriculture was later revised to accommodate for Bachelors, Masters and Doctoral degree levels.

Alemaya College was independent and was run by its own ‘’president’’ until the establishment of Haile Selassie I University (now Addis Ababa University) in February 1961 and Alemaya College became one chartered unit of the University with a new name ‘Haile Selassie I University College of Agriculture’. On July 1966, the post of the president was abolished and the college was run by a Dean. The contractual agreement with the USA terminated in 1968 and the College was run fully on Ethiopian government budget. The College remained a chartered member of the Addis Ababa University until 27 May 1985, the date of its upgrade to a university level.

Alemaya College of Agriculture, the Institute of Animal Health Assistants, Ambo and Jimma Institutes of Agriculture used to offer university-level education in agriculture until mid-1970s (Belay, 2010). After that different colleges of agriculture and other agriculture-related institutions have multiplied around the country. At present, most public universities offer various levels of degrees in agriculture and related fields.

Agricultural Technical and Vocational Education and Training colleges and Farmer Training Centres are also operational. The Agricultural Technical and Vocational Education and Training Colleges are funded and managed by Federal and/or Regional Governments. At present, 25 such colleges throughout the country are training middle level agricultural experts in Animal Health, Animal Sciences, Cooperatives, Natural Resources Management and Plant Sciences. The duration of study is three years, two years in campus and ten months apprenticeship. The Farmer’s Training Centers inform, train, and advice farmers and demonstrate practical operations in the field. These centers are found at the village level and they bridge extension activities and farmers in agriculture (Davis *et al.*, 2007).

What good were higher education institutions in agriculture anyway? Their mandate was to build capacity of experts, enhance skills, conduct quality and relevant research, contribute to the national extension drive, and to forge some organic and symbiotic community engagement (Belay, 2010). Their functions should be aligned with national strategies for meeting the challenges of food security, economic growth, and sustainable environmental management (Aregay, 2004; Belay, 2008; Davis *et al*., 2007). This was an attempt to minimize the severe shortage of skilled manpower, solve persistent challenges through scientific research and contribute in community development.

Cognizant of the role the sector plays for the national economy, successive Ethiopian governments have invested in agricultural research. According to Bechere (2007), several institutions were involved in agricultural research in Ethiopia including Ambo Plant Protection Research Center (est. 1972), Institute of Agricultural Research (1955) with centers distributed around the country, Plant Genetic Resources Center (1974), later the Biodiversity Institute, Forestry Research Center (1975), Wood Utilization Research Center (1979), National Soils Laboratory (1989), and Institute of Animal Health Research (1992). Higher education institutions were also involved in agricultural research since the distant past including Alemaya University (1953), Hawassa College of Agriculture (1977), Wondo Guenet College of Forestry (1978), Faculty of Veterinary Medicine at Debre Zeit (1979), and Mekele University College. Recently, other old or new universities (such as Bahir Dar University) were also involved in training and research in agriculture.

## **Implementation of 70:**30

Science education was run on the basis of bands identified, i.e., Natural Science students grouped in four bands: Engineering and Technology (band-1), Natural and Computational Science (band-2), Medicine and Health Science (band-3) and Other Agriculture and Natural Resources (band-4) (Asfaw and Gashaw, 2021).

Higher education instills relevant knowledge and advanced skills and supplies the human resources required for leadership, management, business and professional positions (Teshome, 2017). A quantitative study was conducted to compare higher education institutions (public and private) in Ethiopia in terms of implementing 70/30 professional and program mix intake policy using cross-sectional survey research design. For the purpose of comparison, 32 public universities were selected and grouped into 1$^{st}$, 2$^{nd}$, and 3$^{rd}$ generations on the basis of their years of establishment.

The findings show that though net entry rate has increased, there was a wide gap between policy and practice in implementing 70:30 policy among the three generations of public higher education institutions and their respective bands with high enrollment to natural sciences and technology fields, and less of humanities and social science fields (Teshome, 2017).

The share of private enrollment was low and gender mix was not balanced. Public higher education institutions give priority to sciences, engineering and technology fields, and private higher education institutions mainly focus on business, social sciences and humanities. To narrow the gap between policy and practice, universities and national students' placement offices need to work closely, and carefully consider the national intake policy and align their intake with the country's future human power requirements.

Strong link and collaboration needs to be established between government and nongovernment institutions to fairly benefit from reforms introduced at different times. Low achieving and female students need to get necessary support to minimize imbalance of gender, and to improve enrollment and graduation rates in public higher learning institutions. Since social sciences fields can help in combating contemporary global challenges like corruption, terrorism, problem of good governance and other social disorders, universities need to heighten their priority towards this field.

## Science research in Ethiopia

Ethiopia's research production is severely deficient, i.e., low number of researchers (45 per million inhabitants), less than half than the African average (Fosci *et al.*, 2019). The government employs over half of them (56%), and the rest are employed in higher education institutions. In 2013, gross expenditure on research and development was less than 1% of the GDP (0.6%), lower than the government objective of 1% but up from just 0.17% in 2007 (UNESCO). The number of universities has grown considerably (from 2 in 1991 to dozens in 2010s) but it still remains insufficient to serve a country with over 110 million inhabitants. Functioning universities also contribute little to research production (UNESCO) (Fosci *et al.*, 2019). Non-academic organizations or institutes conduct much of the research, and research capacity building and donor support in research is extremely low compared to other Sub-Saharan African countries. Research infrastructure, both physical and digital, remains underdeveloped (World Economic Forum).

Higher education research in Ethiopia is fragmented and inadequate. Absence of incentives, burden from other activities and lack of commitment constrain **research** undertaken by academic staff (Umer, 2020). It still suffers from shortage of finance, lack of data base for research work and lack of effective link to industry. English language problem, low number of PhD holders, adoption of foreign policies, influence of international organizations, and lack of adequate stakeholders' participations all have their negative role to play. Research and industry are still not satisfactorily linked. Fragmented research activities, lack of organizing body responsible for making knowledge generated usable for policymakers, lack of a system of evaluation for research, very routine and tiresome financial procedure, and duplication of research efforts confound the problem. Staff capacity building, an organization linking research and policy makers will help solve some of the constraints mentioned here (Umer, 2020).

## FINANCING HIGHER EDUCATION IN ETHIOPIA

The education sector in Ethiopia is financed by the government. On average, about a quarter of the national budget is allocated to the Education sector (about 15 to 20% of this to the Higher Education and 45 to 60% to the Education subsector as a whole) (Bechere *et al.*, 2015). In 2014/15, the budget of Higher education has increased from less than half a million Birr in 2000/1 to about 6 billion Birr. The government has also implemented students' cost sharing scheme for the undergraduate program, where students are subjected to pay 15% of all costs incurred by the government. A few Ethiopian universities, i.e., Addis Ababa, Haramaya, Mekele, Bahir Dar, Jimma, etc. often provide scholarships to selected students of the neighboring countries, such as Eritrea, Somalia, Rwanda, etc. Proclamation No. 650/2009 gives the authority to Higher education institutions to generate their own income, and use it to strengthen their institutional capacity. Financial dependence of the universities on the government is argued as a limitation because it decreases competition, and hampers institutional innovation (The World Bank, 2000). On the other hand, universities are expected to satisfy public interests, and this can only be ensured through the enforcement of the state. So, in the short-run, it had better stay within the government, while in the long-run, it could be by its own (in terms of like ownership, level of sophistication and financial outlays). Government ownership is for social benefits, while funds for research are secured primarily from external sources.

## SOME CHALLENGES

Previous reforms have substantially increased financing, improved access and enrollment as well as transformed governance of the higher education system (Shibru *et al.*, 2015). However, despite the good access to higher education in Ethiopia in the last two decades, important gaps, such as quality and relevance, equity, leadership and governance issues still remain a handicap. There are currently 176 undergraduate and more than 300 postgraduate academic programs in Ethiopia, with 35% female, and 15% private students enrolled (Shibru *et al.*, 2015). Of these, 50 undergraduate, 74 Masters, and 22 Doctoral programs are related to agriculture in public universities. Because of changing scenarios, the training in various degree programs should target employment, job creation and other opportunities in the immediate future.

The massification of Ethiopian higher education institutions with special emphasis given to Science and technology education had challenges of its own (Tasisa and Panigrahi, 2013). Quality of education declined and pressure increased on the existing higher education system of the country in an effort to respond to the needs of the society and build a base for development. Poverty had to be eradicated, and the country joins middle-income level, which universities had roles to play.

Challenges of higher education in agriculture are also a handicap. Most of these are also challenges of other fields of science and technology in general. The present staffing situation shows a chronic shortage of highly qualified and experienced staff, inadequate supplies and equipment, lack of up-to-date reference books and journals, poor practical training, dominance of traditional teaching methods, severe shortage of ICT facilities and connectivity, narrowly-focussed academic programs, low reference to local or Ethiopian conditions in teaching, poor inter-institutional linkage, and poor communication with key Stakeholders.

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**Acknowledgements**

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Steel, R.G and Torrie, J.H. (1980). **Principles and Procedures of Statistics**. McGraw-Hill, New York.

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Lechevalier, M.P and Lechevalier, H.A. (1980). The chemotaxonomy of Actinomycetes. In: **Actinomycete Taxonomy, Society for Industrial Microbiology**, pp. 227-291 (Dietz, X. and Thayer, Y., eds.). Arlington, VA.

Melaku Wale (2015). *Acyrthosiphon pisum* (Harris) pushes cool-season food legumes to extinction in Ethiopia. In: ***Pisum sativum*: Cultivation, Functional Properties and Health Benefits**, pp. 91-111 (Becket, S., ed.). Nova Science Publishers, New York.

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Eshetu Derso, Teame Geberzgi and Girma Adugna (2000). Significance of minor diseases of *Coffea arabica* in Ethiopia. In: **Proceedings of the Workshop on Control of Coffee Berry Disease (CBD) in Ethiopia**, pp. 35-46, Addis Ababa, Ethiopia.

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Alberts, M.J.A. (2004). A comparison of statistical methods to describe genotype × environment *interaction* and yield stability in multi-location maize trials. M. Sc. Thesis, University of the Free State, South Africa.

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Toni, R.L and Culvert, L.L. (2003). Safer Hospital Stay and Reducing Hospital-Born Infections. *Health Scout News*. http://www.healthscout.com, (Accessed January 9, 2010).

Khan, M.H., Mubeen, S.M., Chaudhry, T.A and Khan S.A. Contact lens use and its compliance for care *among* healthcare workers in Pakistan. Indian Journal of Ophthalmology [Epub ahead of print] [cited 2013 Nov 12]. Available from:http://www.ijo.in/preprintarticle.asp?id=97552.

Dorji, D., Dendup, T., Malaty, H.M., Wangchuk, K., Yangzom, D and Richter, D.J. Epidemiology of *Helicobacter pylori* in Bhutan: The role of environment and geographic location. *Helicobacter* 2013, doi: 10.1111/hel.12088 (Accessed September 23, 2013).

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**ACKNOWLEDGEMENTS**

Please acknowledge anyone who did substantial contributions to conception, design, acquisition of data, or analysis and interpretation of data, or who was involved in drafting the manuscript or revising it critically for important intellectual content, but who does not meet the criteria for authorship. Please also include the source(s) of funding for each author, and for the manuscript preparation. Please also acknowledge anyone who contributed materials essential to the study.

**DECLARATIONS**

- Ethical Approval and consent to participate statement
- Availability of Data
- Conflict of interest
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