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PROCEEDINGS OF THE CAPACITY BUILDING WORKSHOP ON INCLUSIVE/COMMUNITY BASED INNOVATION FOR AU MEMBER STATES

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Table of Contents

Foreward

This proceeding is the output of the workshop on Inclusive/Community-based and Inclusive Innovation for AU Member States. It falls under the broader initiative of the African Union Scientific, Technical and Research Commission (AU-STRC) programme on Community-based and Inclusive Innovation (CBI) and it was in response to the consideration of the role that inclusive innovation plays in the creation, prioritization and delivering of high performance products and services at ultra-low cost to the people whose needs are generally not addressed at the base of the pyramid (BOP). The Workshop took place from 10-12 December, 2018 in Abuja, Nigeria and comprised of participants, drawn from various fields of knowledge from across AU Member States.

Africa is characterized by great diversity in terms of the functioning and maturity of markets, research and innovation systems, education systems, the institutional environment, economic and political conditions. In recent years, we have seen a positive overall trend regarding governance, economic stability, investment climate and microeconomic conditions. At the same time, however, significant challenges to development remain, particularly regarding the provision and inequality of healthcare and education, inadequate infrastructure (physical and digital), energy supply, governance and the framework conditions for doing business, all of which are vital towards achieving Africa's resilience.

Africa's future is better served by adopting inclusive solutions that are tailored to our community needs and challenges, which reward approaches that enhance its potential that would otherwise be costly for governments or businesses in Africa to take. Therefore, I call upon my colleagues' ministers of Science and Technology to consider CBI as a driving force for the African economy from which we can achieve sustainable development within the continent that in my view, would make a real difference in the lives of our people. This will require commitments of resources, cooperation and partnerships among all stakeholders.

African scientists are to lead the continent by responding to our development needs by utilizing our science to respond to Africa's market demand and to consider our community needs as a lighthouse for their research

Dr. Ogbonnaya Onu
The Honorable Minister of Science and Technology
Federal Republic of Nigeria

Background to the Proceedings of the Workshop on Inclusive/ Community-Based Innovation for AU Member States

The Workshop on Inclusive/ Community-Based Innovation for AU Member States is a part of larger initiative on the programme of inclusive/community-based innovation of the African Union Scientific, Technical and Research Commission (AU-STRC) that is in consonance with the global Sustainable Development Goals and its implementation strategy that needs inclusive innovations in 14 out of the 17 goals in attaining its desired objectives. The overarching continental framework the AU Agenda 2063 and its aspirations called for renewed approach in addressing the bottom of the consumer pyramid which is over 80% population in Africa. The Agenda aims to deliver on its goal for inclusive and sustainable development and is a concrete manifestation of the pan-African drive for unity, self-determination, freedom, progress and collective prosperity pursued under Pan-Africanism and African Renaissance.

The Agenda 2063 has several sectoral policies and strategies in implementation within the continent and realizing the key role of Science, Technology and Innovation (STI) in Africa's development, the 23rd Ordinary Session of African Union Heads of State and Government Summit adopted the Science, Technology and Innovation Strategy for Africa (STISA-2024) in June 2014. The STISA-2024 is a 10-year strategy developed to leapfrog Africa on the right path to achieving the Agenda 2063 with science, technology and innovation as multi-function tools and enablers for achieving continental development goals.

In the implementation of the (STISA-2024) there are many programmes and projects that are ongoing and inclusive innovation and community-based innovation became indispensable elements in most of these projects. Inclusive innovation is any innovation that leads to affordable access to quality goods and services for the poor on a sustainable basis, serves a real need, effective and with extensive outreach. While community based innovation are innovations that are driven by community needs where research institutions are more informed with their local community needs. While, community-based innovation is defined as an innovation that is motivated by the bottom (Users Community/ beneficiary and Community challenges) top approach (Universities, research centres, and research). Also, it can be defined as any innovation that gives local community best possible quality solution for their daily challenges.

Inclusive/community-based innovations within the realm of technology presents an opportunity for wealth creation and plays a critical role in the socio-economic development of AU Member States by re-directing innovation to address the needs of the people at the base of the consumer pyramid. The process of applying new and improved knowledge in an inclusive approach is central foci for development. In Africa, capacity to utilize knowledge, application of new knowledge in productive activities of inclusivity is proven to be successful as experienced in

mobile money transactions, the Hippo Roller water solution, and agribusiness crowd-farm amongst others.

Moreover, the most successful economies in the world are innovation-driven, with a greater percentage being in STI, because creation of new ideas and technologies leads to invention of product solutions, services, and infrastructure which improve human standard of living or quality of life significantly. Hence, Africa needs innovation that is inclusive enough to effectively serve the rural population. Also, for maximal efficiency, complex technology must be simplified to directly address the needs of our communities. There are also notable challenges on the path of success on the Inclusive/ Community-Based Innovation are the inability of the few home-grown innovative science and technology products available to reach the market, consumers and effectively compete for market share. In some cases, innovative prototypes from research do not achieve the mass-production phase. The reasons for this gap between the laboratory bench and the market vary from lack of funding to lack of entrepreneurial acumen of African scientists to the lack of adequate connection and partnership between scientists and industrialists/entrepreneurs with the resources and platform to convert research findings into product solutions and scale up production into commercial quantities.

This Workshop which took place from 10th to 12th December, 2018 in Abuja, Nigeria was initiated towards addressing the challenges and participants were selected scientists, academia and industrialists drawn from about 20 AU Member States. The opening ceremony started with key note addresses from notable representative of Ministry of Science and Technology, Ministry of Trade and Investment, and other high profile scientists within the continent. Subsequently followed by presentation of various topics according to the Workshop programme that includes: Presentation on African Union Policies on Science Technology and Innovation & Trade and Industry (AU frameworks supporting STI development in Africa); Comparative Analysis of STI Contribution to National GDP of the Developed and Developing World; Approaches to innovation for clean sustainable and inclusive growth of developed and developing world; Inclusive Innovation as a driving force for Africa's growth and Economic Prosperity; Redesign Your Brain: Think Inclusive & Community-Based Innovation.

There was a panel discussion on Capacity Building (Technical & Professional Competencies) in Africa, as well as Linking Industry and S&T. Finally, with a view to practicalizing and localising the programme objectives, there were panel discussion sessions based on Success Stories on Inclusive and Community-based Innovation already recorded in Africa were presented.

The need for the documentation of the presentations stem from the quality and the content of the papers presented, this necessitated the workshop to recommend the publication of the workshop proceeding. The AU-STRC serialized the proceeding as an academic reference material and be distributed to institutions.

Africa is at a Turning Point: Financial Mechanisms and Instruments for Inclusive and Community-Based Innovation

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Abstract

The challenge of financial inclusion is not new to Africa. Rural women particularly have limited access to financial services, particularly to the levels of credit required to expand their businesses. Their access to financial services is held back by legal obstacles, cultural assumptions and common banking practices.

Key words: *Financial Inclusion, Rural Women, Collateral, Banks, Financial Mechanisms and Instruments, Inclusive and Community-Based Innovation*

1. Introduction

Many countries have achieved high growth rates over the past decade, and many aspire to structural transformation, but the good performance has not translated into significant poverty reduction and shared prosperity (African Development Bank Group, 2015.).. It has yet to provide low-income households and other vulnerable groups enough opportunity to improve their living standards. In terms of economic indicators, North Africa was performing well, but the young, low-income earners, and other vulnerable groups had been excluded from employment opportunities and other means of generating livelihoods to enable them to exit poverty (Pluess and Jorgensen, 2014.). The civil unrest and social and political tensions of the so-called "Arab Spring" were a reality check to many countries in North Africa to be more inclusive. (FEMNET, 2012).

Africa is now the world's second fastest growing region after Asia, with annual GDP growth rates in excess of 5% over the last decade. (UNDP, 2016) Despite this growth, the "Arab Spring" events showed that good economic growth in the continent had not translated into shared prosperity and better livelihoods for the majority (Pluess, 2016). Growth has to be inclusive to be socially and politically sustainable. One key component of inclusive development is financial inclusion, an area in which Africa has been lagging behind other continents (AfDB, 2011). Less

than one adult out of four in Africa have access to an account at a formal financial institution. Broadening access to financial services will mobilize greater household savings, marshal capital for investment, expand the class of entrepreneurs, and enable more people to invest in themselves and their families. Financial inclusion is therefore necessary to ensure that economic growth performance is inclusive and sustained. (Herring, 2009; Credit Suisse, 2012.)

The challenge of financial inclusion is not new, but the social explosion in North Africa has been an eye-opener for policymakers everywhere, and for the development community as whole (AfDB, 2016). A clear paradigm shift has resulted in a more inclusive and sustainable growth agenda. For its part, the African Development Bank (AfDB) has launched its Ten-Year Strategy 2013–22, the main thrust of which is inclusive and green growth. The concept of inclusive growth is (Woetzel, et al., 2015) multifaceted and has financial inclusion as one of its main building blocks. For sustained and inclusive development to thrive, a great deal of innovation and thinking is needed to ensure that appropriate financial services and instruments are put in place for the benefit of the poor and other vulnerable groups. Financial inclusion is a multidimensional concept that encompasses all initiatives, from both supply and demand sides, within the financial sector (IFC, 2013). They include provision of appropriate and quality financing that is both accessible and affordable to low-income and other vulnerable households. Notably they target groups traditionally excluded from the formal financial sector. (Golla, etal 2014)

This discussion is a novel effort in at least three different ways. First, it contributes to our understanding of the issue of financial inclusion, on which there is little research to date. In doing so, this paper provides a comprehensive definition of financial inclusion and discusses issues related to measurement (Noland, 2015). Further, it explores what financial inclusion really means from a number of different perspectives including small and medium enterprises, women, rural areas and agriculture, and fragile states, and provides strategic options for its promotion. (UNW Report, 2011)

The objective of this paper is to contribute into the debate on financial inclusion on the continent while documenting the state of financial inclusion in Africa and informing policymakers, financial sector stakeholders and development actors about existing opportunities and specific challenges that need attention and action. It describes the multifaceted nature of financial inclusion through a compilation of sections discussing the topic from different perspectives (Brunelli, 2015). It is structured around three main parts. The first part lays the groundwork for the subsequent analyses, the second part looks at some transformational mechanisms and approaches designed to serve the underserved, and the third part tackles strategic issues and options. (Campos, 2014)

2. Methodology

The paper is narrative, interpretative and analytical on the subject matter and uses multiple methods to collect data. It uses qualitative methods of enquiry, reviewing both primary data as well as secondary data in the area of “Financial Inclusion”, “Rural Women”, “Collateral”,

"Banks", "Financial Mechanisms and Instruments", "Inclusive and Community-Based Innovation". A qualitative research design is used to collect data. This analysis is based on new and unique datasets. This enables contributors to rigorously analyze financial inclusion from the point of view of segments of the population, users groups, or sub-regions served by the formal and informal financial services in Africa. (Warring, 2017)

3. Results

Financial inclusion refers to all initiatives that make formal financial services Available, Accessible and Affordable to all segments of the population (World Bank, 2015). This requires particular attention to specific portions of the population that have been historically excluded from the formal financial sector either because of their income level and volatility, gender, location, type of activity, or level of financial literacy (Moodley, et al 2016). In so doing, there is a need to harness the untapped potential of those individuals and businesses currently excluded from the formal financial sector or underserved, and enable them to develop their capacity, strengthen their human and physical capital, engage in income-generating activities, and manage risks associated with their livelihoods. (FAO Report, 2011)

Financial inclusion goes beyond improved access to credit to encompass enhanced access to savings and risk mitigation products, a well-functioning financial infrastructure that allows individuals and companies to engage more actively in the economy, while protecting users' rights (ILO, 2016). Interest in and dedication to promoting financial inclusion has grown dramatically in recent years, as seen in the number of countries that committed to the Maya Declaration and the G-20 Financial Inclusion Action Plan, as well as strategies and targets set by individual governments. (World Bank Report, 2015)

To track progress in achieving more inclusive financial systems and gauge their impact, a clear and unified definition of financial inclusion is needed and data collection efforts must be aligned with growth in financial inclusion commitments and programs (Jahan, et al 2015). Rigorous, well-tailored data is instrumental to identify policy gaps, understand both served and underserved populations, and define priorities for action. (MDG Report, 2013)

While data availability is increasing, many international data sets only cover part of Africa, and African countries are yet to implement nationally-led surveys of financial inclusion at a larger scale (INTEL, 2017). More can definitely be done to increase the coverage and scope of financial inclusion data on the continent (Chant, 2013). With a focus on Africa, this chapter provides a more comprehensive definition of financial inclusion while describing its main dimensions that require measurement, outlines existing sources of data on financial inclusion, and gives an overview of recent initiatives to develop global indicators on financial inclusion as well as options for national-level data collection. (Micro-Finance Report, 2011)

A Foundation for Measurement Definitions and measurements of financial inclusion have evolved from classifying individuals and enterprises according to a dichotomous division as either included or not, to viewing financial inclusion as multi-dimensional (IFAD, 2016). With

the aim of defining a more complete concept of inclusion, the Financial Inclusion Data Working Group of the Alliance for Financial Inclusion (AFIFIDWG) agreed on three main dimensions of financial inclusion that provide the underpinning for data collection: access, usage and quality (Gammage, 2012).

The adoption of broader and multidimensional definition of financial inclusion is crucial in the sense that it helps to move beyond the often-erroneous assumption that inclusion will inevitably be achieved by simply offering enough access points (Mcarthy, 2010). Instead, a more complete understanding of financial inclusion should speak to how frequently clients use products, if the products are effectively meeting their needs, and if they are better off as a result (World Bank Open Data, 2010). Therefore, defining and measuring usage and quality in addition to simple access would be very useful for analytical purposes (MDG Report, 2011). These three dimensions of financial inclusion are broad categories into which indicators can be grouped, without being restrictive. They simply provide a framework to guide policymakers in developing a sufficiently robust measurement strategy that reflects the multi-dimensional nature of financial inclusion. Within this framework, policymakers will still need to design a set of indicators appropriate to their needs and level of resources (UNDP, 2008).

Although efforts to promote financial inclusion should strive to improve all three dimensions simultaneously, when setting priorities for measurement, a number of countries are now gathering information sequentially, assessing access first, usage second, and examining quality third (World Bank, 2015). This is often because in most countries, data on the level of service provision is more easily obtained than usage and quality data (Okoye, 2003). In Africa, many countries are now at the level of collecting mostly access and some usage data. However, in countries where the FinScope Surveys are carried out, usage and quality data may be more easily available than access data because of the surveys' focus on these dimensions. (Smith, 2000)

To better capture financial inclusion, it is crucial to start with fully analyzing and understanding the existing data (Montenegro, 2016). A number of institutions, mainly donor-funded, have invested significant resources in measurement of financial access and usage, globally and in Africa, with a particular focus on the supply side (UNESCO, 2016). Financial inclusion data has traditionally been separated into supply and demand-side information. Supply-side data comes from providers of financial services, while demand-side data involves interviews with end-users of products: individuals, households, and firms (Kutinyu 2012). Central Banks often collect some supply-side data as part of their supervision duties for regulated institutions, and this can be a good source of information at the national level. However, supply-side data provided by central banks or supervisory bodies on the number of accounts and Automated Teller Machines (ATMs) in a country is not detailed enough to provide information about how many people have accounts (due to multiple accounts held by some individuals) and how access varies by region, income level, and other variables. In some countries central bank data may not provide a useful level of granularity about financial access. (AfDB, 2015)

The most frequently (80% of adults without formal accounts surveyed) cited reason for not having a formal account in Africa is lack of enough revenue to use one (Abbey, 2016). Cost, distance, and documentation are also cited by more than 25% of non-account-holders in Africa (Addati, et al., 2014.). In East Africa, cost is the second most frequently cited reason at 46% and distance is the third. In East and West Africa, documentation is the second most cited reason with 36% of adults giving this as a reason (Kirigia, et al., 2014). Fixed fees and high costs of opening and maintaining accounts seem to be hindering factors in Eastern and Southern Africa (Okech, Wawire, and Mburu, 2011). For example, in Uganda maintaining a checking account costs the equivalent of 25% of GDP per capita annually, a good reason to not have an account (Alkema, etal, 2013). In Africa, insufficient documentation is an important barrier for younger adults to open an account while distance from a bank is a commonly cited barrier for adults living in rural areas. Adults with a primary education or less, on average, are more than three times likely to cite insufficient documents as a reason when compared with adults with a tertiary education or more (Humphrey, 2012). Cost and distance are also commonly cited among adults with a primary education or less. Bringing financial services to rural clients is a major challenge on the financial inclusion agenda (Rubin, 2014).

Often the main barrier to financial inclusion in rural areas is the great distances that rural residents must travel to reach a bank branch (FAO, 2016). Poor infrastructure and telecommunications, and heavy branch regulation, also restrict the geographical expansion of bank branches (CGAP, 2009). Indeed, financial inclusion is positively and significantly correlated with access points measured as commercial bank branches per 100,000 people (Brown, 2013). Sub-Saharan African economies are at the low end of the spectrum with a low number of commercial bank branches per 100,000 adults and low account penetration. The lack of infrastructure may explain why Africa has been at the forefront of mobile financial services which is considered a bright spot in improving financial inclusion. (Betron, 2008)

The great financing constraints faced by SMEs, especially in accessing bank finance limit these firms' growth opportunities (Sinclair, 2017). To gain a better understanding of firms' access to finance in Africa, data from the World Bank Enterprise Surveys (WBES), which cover more than 130,000 firms in 127 countries, is analysed. On average, the percentage of enterprises with a bank account (across all firm size groups) in Sub-Saharan African countries is comparable to or greater than the percentage of enterprises with a bank account in all other developing economies (UNDR Report, 2016). For instance, 83% of small-sized enterprises and 94% of medium-sized enterprises in Africa 54 report having a bank account as compared to 87% of small-sized and 93% of medium-sized enterprises in other developing economies. (World Bank, 2015)

A similar pattern is observed for North Africa. In Algeria, 84% of SMEs and 83% of large enterprises report having a bank account (Kenya National Bureau of Statistics, et al., 2015.). In Morocco 79% of small and 87% of medium-sized enterprises have a bank account.7 In Egypt, on average, 74% of firms have a checking account (SADC Report, 2011). Yet, firms in Sub-Saharan Africa have notably limited access to external funding. WBES data show that on average, only 22% of enterprises have a loan or a line of credit. In comparison, the average of enterprises with

a loan or a line of credit in other developing economies excluding Africa is 43% (AfDB 2010). Like elsewhere, small firms in Sub-Saharan Africa are at a relative disadvantage in accessing external credit. In Sub-Saharan Africa, 45% of firms cite access to finance as a major constraint to growth (Fannin, 2010). However, a higher percentage of small firms identify access to finance as a major constraint relative to medium and large enterprises (Mack, 2009). Similar results hold for firms in North Africa. 16% of small-sized and 44% of medium-sized enterprises have a loan or line of credit. In Morocco these percentages are 20 and 28 respectively. (Prinn, 2008)

Individuals' Access to Finance Africa's financial system's underdevelopment and its limited outreach are well documented (IMF, 2016). Low- and volatile-income levels, inflationary environments, high illiteracy rates, inadequate infrastructure, governance challenges, and the limited competition within the banking industry as well as high cost of banking in Africa are some of the factors used in explaining the underdeveloped financial sector and its limited outreach (World Bank, 2016). However, until recently, very little was known about the actual reach of the financial sector. In what follows we examine access to finance from the point of view of individuals, and look specifically at different aspects that encompass the extent of usage of formal financial services, potential barriers, informal sources of finance, impact on the savings behavior of individuals as well as their borrowing needs and reasons for access to credit (Seth, 2015).

Indicators of financial use by individuals show a positive but imperfect correlation with indicators of financial depth such as credit to the private sector as a share of GDP (Wakinyu, 2012). This correlation shows that access to finance is really a distinct dimension, suggesting that financial systems can become deep without delivering access to all. The positive but imperfect correlations of financial services usage with financial depth raise questions regarding the drivers of cross-country differences in financial use and access. The correlations also suggest that there might be room for policy reforms to increase the level of financial inclusion (World Bank, 2008).

4. Discussion

Financial inclusion is a multidimensional concept that goes beyond access to encompass usage and quality (Hossain, et. al., 2016). Hence, a comprehensive understanding of financial inclusion should consider the availability and accessibility of services, frequency of use, and suitability and quality of financial options for all income levels (Kassongo, 2014). A financial system that is fully working for clients should also offer opportunities to easily access information about available products and their terms, and should establish rules protecting the consumer from deception or exploitation (Shell Foundation, 2014). While there are a number of high-level supply and demand-side indicators on financial inclusion available from international sources, regional and conceptual gaps must be filled in order to construct a comprehensive picture of financial inclusion in Africa. (WEP, Report, 2012)

Specifically, on the supply side, the availability of information on non-bank financial services, such as microfinance, cooperatives, mobile financial services, and in some cases agent banking, could be improved (Murange, 2017). Little information on consumer protection has been

standardized and collected across African countries. On the demand-side, many countries in Africa are lacking a larger-sample national survey of consumers that allows for segmentation according to income, region, and other covariates. Data on financial capability, SME access to finance, and measuring the impact of greater financial access is notably sparse as well (Vodafone, 2015).

While measuring such a multifaceted topic is challenging, the AFI Core Set of Indicators is an important starting point, providing a snapshot of access and usage of basic formal financial services (Safaricom, 2014). Developing reliable, evidence-based metrics for quality and welfare, as well as effectively combining supply and demand-side data lie at the frontier of financial inclusion measurement (Kinnros, 2013). From the findings in this chapter, a few key recommendations could be made to further support the development of financial inclusion data in Africa: African policymakers concerned with understanding financial inclusion in their countries should advocate for national demand-side surveys (Suzzaine, et. al., 2009). Relying on supply-side data collected by national regulators and supervisory bodies is not sufficient given that the latter does not capture information on usage and quality. (MDG Report, 2008)

When interventions to improve financial inclusion are planned, policymakers and development partners may wish to undertake a baseline and follow-up analysis, and to randomize the distribution of the incentive or product if possible, in order to effectively measure its impact (Millicom, 2015). This would allow a proper assessment of the interventions and revision if needed. Financial inclusion champions are needed (Tigo, 2015). Providing for a dedicated unit or staff member in the central bank, ministry of finance, national statistics office, or other organization is useful as it helps to have one clear advocate coordinating research efforts and advocating for more financial inclusion data. (Cisco, 2014)

5. Conclusion

Despite the recent financial sector growth in Africa, many individuals and firms are still excluded from access to formal financial services (Rawlands, 2015). Analysis of the usage of (and access to) financial services by adults and enterprises shows that African countries lag behind other developing economies in both aspects, and that cost, distance, and documentation requirements are important obstacles. Analyzing individual characteristics provides an opportunity to identify the demographic groups that are particularly excluded from the financial system (Bari, 2014). For example, those living in rural areas, the poor, women, less educated adults, young and older adults particularly face challenges in financial inclusion.

Barriers faced by both households and enterprises tend to decline as per capita GDP rises, and in countries with more competitive, open, market oriented and well-regulated financial systems with more developed contractual and informational infrastructures (World Bank, 2008). Removing physical, bureaucratic, and financial barriers to expand financial inclusion is challenging since this also requires addressing the underlying structural causes such as low-income levels and governance challenges (Newmont, 2006). Nevertheless, measures to improve contestability of financial systems and underlying information and regulatory environment are also likely to speed up the introduction and adoption of new products, processes, and technology

that may help further lessen these barriers in Africa (ILO, 2006). The most evident example is the recent success of mobile money in East Africa which shows that innovations can bring about dramatic changes in how people engage in financial transactions by lowering entry barriers, reducing costs, and expanding access. (Kukere, 2005)

6. Addressing the SME Barriers – IFC Support to Financial Institutions Nigeria

Access Bank PLC Nigeria is a leading African bank that decided to become an early mover into the women SME space in Nigeria and is part of a coordinated program (Enterprise Development Center, Fate Foundation and IFC) focused on improving financing for women-owned SMEs. Access Bank offers customized credit lines to women entrepreneurs and tailored training courses in financial literacy, business management skills, and trade finance in order to become the bank of choice for Nigerian women entrepreneurs (Okoye, 2016). By the end of 2010, USD 35.5 million loans had been disbursed over a 4-year period with a non-performing loan rate of 0.5 percent, and close to 700 women had been trained by the program. (Obi, 2014)

6.1. East Africa

Diamond Trust Bank (DTB), one of East Africa's leading banks with a network of 70 branches in Kenya, Uganda, Tanzania and Burundi, has made a strategic choice to systematically target the SME sector which currently represents over 70 percent of its loan portfolio (Solar, 2017). To ensure the sustainability of its operations, expand offerings and deepen regional collaboration, DTB is making additional efforts to develop a strong SME banking network across East Africa, with technical support from IFC (Finland, 2016). One of the enhancements to better serve the SME market include the usage of a web-based cash management service, an online banking platform for SMEs and mobile payment solutions (Sutherland, 2015). Results are encouraging—DTB's SME loan portfolio has grown by 42 percent to date, representing an additional 1,468 outstanding loans, valued at USD 130.58 million for the group. (Knowles, 2012)

Africa's SME finance gap is wide. On average, one out of two firms in Africa is financially unsaved leading to an over USD 100 billion credit gap for SMEs alone (AfDB, 2015). The funding gap is particularly acute for very small firms with typically less than 9 employees, very small and medium firms with one or more women owners, and firms operating in the informal sector that are often overlooked by the traditional banking sector (WHO, 2013). Addressing these needs with only traditional finance solutions will not be sufficient. Africa requires scalable and transformational solutions that incorporate various types of financial services and products and complement financing with capacity building (Kim, 2011). Examples of high-impact SME finance initiatives show that such a holistic approach is needed to address bottlenecks across the financing value chain (Chan, 2010). Technology-based solutions also hold the potential to help accelerate financial inclusion for SMEs in Africa. Transformative solutions also require enablers at the policy level (MGD, 2008).

Some (non-exhaustive) suggestions follow: · To foster alternative SME finance products such as leasing products which are an important source of investment finance, a legislative framework is needed to clarify rights of the parties to a lease, remove contradictions in the existing

legislations, create non-judicial repossession mechanisms, and ensure that tax rules are clear and neutral (World Bank, 2015). · Insolvency regimes are another example where strong credit rights can improve access to finance (Wakinyu, 2014). Given that not all SMEs thrive, a legal framework to address the insolvency of business entities is essential to ensure that the resolution of multiple creditors' conflicting 73 claims are resolved in an orderly fashion and create more extensive opportunities for recovery (e.g., fast track proceedings for small firms with low debt values) (IFC, 2011).

Further efforts are also needed to structure both demand and supply country diagnostics for SME finance and to uncover gender gaps and drivers to improve access to finance for women, small and informal businesses (UNWR, 2016). In this respect, governments and public authorities have a role to play in the collection framework of comprehensive SME data that will help identify the needs as well as the progress achieved (Kenya Bureau of Statistics, 2010). Finally, it is also important to ensure an enabling environment that incentivizes institutions to develop their SME business, and build the efficient and reliable financial infrastructure that helps to better manage credit risk and improve access to credit (Strauss, 2010). Altogether, these approaches call for both public and private interventions and a coordinated action to help Africa's SMEs unlock their potential to be the engines of job creation and economic growth for the region. (BSR, 2009) Examples of Mobile Financial Service Deployments in Africa West African Economic and Monetary Union: Several mobile network operators in the region (Orange, Airtel and MTN) have partnered with banking groups (BNP, Société Générale, and ECOBANK, Bank of Africa) to offer mobile financial services (Moodley, 2016). Eleven (11) mobile financial service offerings are currently available in six out of the eight West African Economic and Monetary Union (WAEMU) countries, namely Benin, Cote d'Ivoire, Mali, Niger, Burkina Faso, Senegal (MDG Report, 2015). These deployments attracted 1.4 million subscribers which is comparable to the number of cardholders in the card-based interbank network as of December 2011(AfDB, 2013). Mobile financial services hold great promises for the region as less than 15% of the population have access to formal financial services while the average telecom penetration rate is 40%. Kenya: M-Pesa is often cited as the pioneer of mobile financial services in Africa. It is currently the leading mobile money service in Kenya, accounting for more than 27,000 agents who handle over 30 million transactions daily. In Kenya 19% of airtime sold was purchased using M-Pesa (UN Millenium Project, 2012).

According to the World Bank "new potential for mobile money has come with the rise of interest-earning bank-integrated mobile savings systems, beginning with the launch of the M-KESHO system in March 2010 (World Bank, 2015). South Africa: mobile financial services are widely used in South Africa with approximately 6 deployments: First National Bank (FNB) with around 2 million customers, Wizzit with over 250,000 subscribers, Flash Mobile Cash by Eezi with a network of 42,000 home shops, MTN Mobile Money, and finally Vodacom, in partnership with Nedbank offering M-Pesa. Tanzania: more than 4.3 million mobile financial transactions have been made since the country introduced such services in 2007, equivalent to 40% of the country annual GDP (SA Treasury Report, 2014). The Bank of Tanzania has encouraged operators to go beyond person to person (P2P) services and offer other mobile financial services

including business to person, business to business, micro savings, micro insurance, micro loans and credit history information. Initial results have been recorded with some mobile financial service providers partnering with local savings groups to provide savings services. (UNDR, 2012)

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Inclusive Innovation as a Driving Force for Africa's Growth and Economic Prosperity

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Abstract

Research has shown that majority of Africans live at the bottom of the economic pyramid. This situation has been compounded by the alienating effects of conventional innovations which has further deepened income disparities between high and low income groups. Inclusive innovations are a class of innovations specifically developed to address the needs of the poor. The paper reviews existing literature on inclusive innovation and draws important lessons for developing a policy and research agenda for sustainable socio-economic development in Africa using inclusive innovations. Some lessons derived from literature include the promotion of indigenous innovations, providing support for research with local relevance, creation of a positive business environment for local entrepreneurs and the activation of institutions that specifically deal with the development and scaling of inclusive innovations.

Key words: *Inclusive Innovations, Economic Prosperity, Inclusive Development*

1. Introduction

Innovation is the application of new ideas to products, processes and other activities of a firm that lead to increased value (Greenhalgh and Rogers, 2010). It incorporates technology into productive sectors, leading to higher and sustained rates of investment and growth. Innovation increases productivity and boosts economic growth. Innovation has become a critical topic of discourse for policy makers, academia and development experts seeking to understand and improve the economic lives of citizenry. It is the driving force of economic development and welfare. Through the provision of new products, processes, business and marketing models, innovation has created new industries, provided employment and higher levels of income, enhanced productivity and improved health and standards of living.

Innovation has however been a source of income inequality and social exclusion, deprivation and alienation in a number of ways (Rangan et al., 2014). Firstly, innovation has increasingly relies on technological advancement. This advancement however requires enhancement in skills sets among the labour force in industries. Therefore skilled groups rather than those that are unskilled will be the beneficiaries of employment opportunities in new industries spurned by new technologies. In extreme cases, unskilled groups may not only become unemployed but also unemployable if new industries using new technologies replace old ones. Secondly, some industries may employ more advanced technologies than others. Therefore, there may be differences in income and productivity across industries. For example, there are large disparities in income of workers engaged in the telecommunications and agro industries. Thirdly, innovation can be labour reducing. The benefits of advances in robotics and its use in production and administration functions have in many industries reduced the number of labour required in those functions. Fourthly, innovations that enhance physical well-being such as drugs and home appliances (such as washing machines, dish washers, carpet cleaners) are targeted at middle to high income groups. Low income groups are therefore left out of any benefits that may accrue from such innovations. Lastly, productivity enhancing new processes and marketing and organisational innovations are usually designed and targeted at formal rather than informal producers, leaving the latter to traditional means of production and failing levels of productivity and income. This is typical of producers in informal sectors such as small-scale agricultural activities (Adejuwon et al., 2014).

The above may also be applied to global inequalities in the standards of living in Western countries and those in sub-Saharan Africa (SSA). Innovation has created centres of technological excellence in developed countries. These centres enable firms in these countries out-compete those in less developed countries in terms of costs, innovativeness, responsiveness to the market and productivity. Product and welfare enhancing innovations from these centres of excellence are out of reach of most people from developing countries in terms of costs and direct benefits e.g., drugs and infrastructure for basic necessities such as water and power. Process innovations from these centres also focus on improving productivity in formal industrial sectors rather than the informal sector where the economies of most developing countries are based. Therefore, in spite of the recent global economic growth, some categories of people in Africa such as women, low income groups, informal sector producers the disabled and people with little or no education among others have been marginalised and have not benefitted from global economic growth. In many African countries, overall economic growth is no longer associated with socio-economic improvements for the poor (Chataway et al., 2014).

The foregoing downsides of innovation have resulted in more acute income disparities not only within African countries but between developed and sub-Saharan African countries. The Gini Index measures the degree of inequality in the distribution of family income in a country. Higher figures represent higher inequality. In the CIA's World Fact Book (2018), Lesotho had the highest figure with 63.2, followed by South Africa (62.5). Nigeria's Gini index was the 21st highest at 48.8. Of the top 40, there were 13 sub-Saharan African Countries. The USA had an index of 45.0 in the 39th position while Sweden (24.90) and Belgium (25.9) were in the lowest 10 at 152nd and 149th position respectively. China's index was 46.5 (29^{th}) while India's was 35.2 (95^{th}).

The notion that economic growth does not necessarily improve the welfare of all has been attracting political and academic interest. There have therefore been calls for more inclusive patterns of growth that emphasizes that economic opportunities created by economic growth are available to all, particularly the poor to the maximum extent possible (Rauniyar and Kanbur 2010). To achieve a more inclusive pattern of growth, especially in the developing world, various strategies have been recommended. Key among these is encouraging the development of inclusive innovations.

Inclusive innovation is the development and implementation of new ideas which aspire to create opportunities that enhance social and economic wellbeing for disenfranchised members of society (George et al., 2012). Inclusive innovation is the creation and adoption of knowledge that is most relevant to the needs of the poor (Dutz, 2007). Foster and Heeks (2013) define inclusive innovation as the inclusion within some aspect of innovation of groups who are currently marginalised.

Addressing the issues of income inequalities within African countries and between African and western countries with inclusive innovations may address problems of economic growth on the continent. Strategies to encourage the development of inclusive innovation have been somewhat successful in China and India due to the deployment of requisite policy interventions. In Africa however, a collective agenda to set up infrastructure for the development and diffusion of inclusive innovations remains to be seen. The aim of this paper therefore, is to draw the attention of policy makers and generate research interest among academicians on inclusive innovation and its role in sustainable development in Africa. This paper is organised as follows. The next section consists of types of inclusive innovation, actors and levels of inclusive innovation. This is followed by suggestions for an agenda and types of institutions that promote the development of social innovations and the concluding section.

2. Inclusive Innovation

Inclusive Innovation is that class of innovations that addresses the needs of persons with low incomes. It may be high or low technology related and based on the efforts of several actors such as private firms, government agencies, non-government organizations, or individuals with little or no formal education. Inclusive innovation is accessible to low income populations, that is people at the bottom of the economic pyramid (Foster and Heeks, 2013; Dahlman, 2014). Global Research Alliance considers inclusive innovation as the creation, acquisition, absorption and distribution of products and services targeted directly at meeting the needs of the low-income groups or the base-of-the-pyramid (BoP) population. The focus of inclusive innovation is to deliver high performance products and services or high experience at ultra-low cost to the people whose needs are generally not addressed. The interest and the purpose of inclusive innovation is not just to promote growth, but to cater for the lower income groups and the poorer segments of the society by providing innovation that increase welfare (OECD, 2013).

2.1. Actors Involved in Inclusive Innovations

For policy and research purposes, it may be necessary to identify the actors involved in the development of inclusive innovations.

2.1.1. The Marginalised

The marginalised groups primarily consists of the low income groups. This group is usually divided into two (Rangan et al., 2014; Chataway et al., 2012) – those who live on below $1.25 a day and those who live on between $1.25 and $2.50 a day. The first group barely have enough income to survive while the latter may suffer from low skill levels and education and malnourishment. They may however still maintain a certain level of consumption power (Chataway et al., 2012). Literature suggests that both groups may require different kinds of innovations. While the better off group may be served by products introduced by Trans-national corporations, the poorer group may require interventions by NGOs. Rangan et al. (2014) reports that individuals who earn below $3 a day may need support to purchase innovations to support business activities.

2.1.2. Multi-National Corporations:

Multi-National Corporations (MNC) may be important players in the provision of inclusive innovations. The motivation to provide inclusive innovations may stem from expanding their markets especially in the provision of consumer goods or corporate social responsibility in the provision of medical interventions (e.g., vaccines and HIV treatment) (OECD, 2013). These MNCs may be based in developed or developing countries. For instance some multinational dairy firms in Nigeria now produce powdered milk in sachet form and sold at price affordable to the low income consumers.

2.1.3. Small- and Medium-scale enterprises (SMEs):

SMEs may also be involved in the development of inclusive innovations. Due to constraints of size, market and resources, they usually focus on solving local problems.

2.1.4. Individual Innovators:

Individuals using indigenous knowledge and/or adaptations may also provide inclusive innovations. These individuals are usually from low income groups and innovate out of necessity or from a feeling of empathy for affected groups (Gupta, 2012).

2.1.5. Knowledge Institutions:

Knowledge institutions are also involved in generating inclusive innovations. For instance, International Institute for Tropical Agriculture (IITA) and other research institutions/ universities in Nigeria have developed quality protein maize and other high yielding varieties of crops which have been transferred to farmers for planting. These innovations must have probably enhanced the income of the farmers.

2.2. Types of Inclusive Innovation

Many practices have been labelled inclusive innovations. Inclusive innovation can be top-to-bottom that is, made for users by Multi-nationals and SMEs or bottom-up, which refers to innovations made by the users themselves. The following are types of inclusive innovation depending on their origin.

2.2.1. Frugal Innovation:

This refers to goods and services that are not of the best quality but that are affordable e.g. low cost smart phones with limited features. NESTA (2012) suggests that frugal innovation responds

to limitations in resources, whether financial, material or institutional, and through a range of methods turns these constraints into advantages. Frugal innovation also refers to systematic attempts by Trans National Corporations to cut out the luxury and unnecessary features of products developed for high-income markets. It seeks to minimize resource usage, costs and complexity in the production, constitution, and operation of new goods and services. For example, Tata in India was able to develop a car selling for less than $2500 (Chataway et al., 2014). Other examples are Procter & Gamble's PuR Purifier of Water (OECD, 2013), the USD 70 refrigerator developed by Godrej & Boyce Manufacturing which runs on batteries, the wood-burning stove produced by First Energy which consumes less energy and produces less smoke and Nokia mobile handsets with simplified menus for wider access, multiple phone books to allow for several users and integrated flashlights (OECD, 2013).

2.2.2. Grassroots Innovation:

This occurs when innovations are produced by members of the very group that the inclusive innovation is supposed to cater for. They are usually introduced to solve local problems (e.g., agro-business, electricity, problems of the disabled) and involve the use of traditional or adapted use of modern technology (OECD, 2013, Kumar and Bhaduri, 2014). Grassroots innovations are usually simple, low cost, easy to apply and replicate and have a large social impact on the livelihood of the marginalised (Kumar and Bhaduri, 2014). For example, a community from Lalvadan Village, Jasdan developed soap from cowdung, panchgavya, multani mitti, sesame oil, camphor etc., with extremely good sanitation properties (Gupta, 2012). Others are the locally fabricated grinding machine used commercially for grinding vegetables in Nigeria, a simple lift to bring agricultural products to a rooftop for drying in China (OECD, 2013), pedal-powered washing machines (the Honeybee Networking India) and water harvesters in India (OECD, 2013). Further examples in Nigeria are locally fabricated oil palm fruit digesters which are used by women oil palm processors. (Adejuwon et al 2014) and grassroot innovations introduced by traditional bone setters in their medical practices. These innovations afforded the low income group access to orthopaedic healthcare services (Asa et al 2017 and Asa et al, 2018). Other grass root innovations are widely used locally made machines for processing of cashew nuts in Nigeria (Oluwale et al, 2017).

2.2.3. Below the Radar Innovations:

These are developed by rural based small – to medium sized firms using locally available resources and new technologies for the poor. Examples are the MoneyMaker Irrigation Pump which is a foot powered pump designed by KickStart International (NGO) in Kenya. The machine costs USD 100 and enables poor farmers irrigate their farms. The pumps have a maximum pumping height of 46ft and a daily irrigation capability of 1.25-2 acres (OECD, 2013). Another example is the computer-based functional literacy (CBFL) program developed by an Indian company to teach an illiterate individual to read a newspaper with only 40 hours of training at a cost per individual of only USD 2 (OECD, 2013).

2.3. Levels of Inclusion of the Marginalised in Inclusive Innovation

Heeks et al. (2014) developed a "ladder of innovation" to indicate the extent of excluded groups in innovation.

Level 1 - Intention: an innovation is inclusive if the intention of that innovation is to address the needs or wants or problems of the excluded group.
Level 2 - Consumption: an innovation is inclusive if it is adopted and used by the excluded group.
Level 3 - Impact: an innovation is inclusive if it has a positive impact on the livelihoods of the excluded group.
Level 4 - Process: an innovation is inclusive if the excluded group is involved in the development of the innovation.
Level 5 - Structure: an innovation is inclusive if it is created within a structure that is itself inclusive.
Level 6 - Post-Structure: an innovation is inclusive if it is created within a frame of knowledge and discourse that is itself inclusive.

2.4. Examples of Institutions Concerned with Development and Scaling-Up of Inclusive Innovations

2.4.1. Empresas Públicas de Medellín, Colombia:
This is a public utility company that specializes in providing energy and water services to low-income users through prepaid mechanisms. In this case, households do not pay fixed installation costs. The essential innovation here is the pay-per-use method introduced by the company. Since the launch of this innovative service in 2007, about 43, 000 low-income users have been connected (OECD, 2015).

2.4.2. Narayana Health, India:
This private healthcare services provider offers low-cost cardiac surgeries and other healthcare services to the poor. It also caters to isolated communities via telemedicine. The firm has scaled its operations to 6,200 beds spread across 23 hospitals in 14 cities (up from an initial 300 beds in 2001) (OECD, 2015).

2.4.3. KickStart (Kenya, Tanzania and Mali):
This firm provides low-cost man-powered irrigation pumps. This innovation requires no electricity or fuel for its functioning. It has resulted in lower irrigation costs in the agricultural sector. The innovation has been scaled to several African countries using local retailers and NGOs.

2.4.4. Mobile Money Transfer Services M-PESA in Kenya:
The leading mobile operator in Kenya, Safaricom launched one of the most successful implementations of a mobile money transfer service, M-PESA in 2007. The product is called M-PESA since “Pesa” is the Swahili word for money and the “M” is for mobile. M-PESA is a SMS-based system that enables users to deposit, send, and withdraw funds using their mobile phone. Customers do not need to have a bank account and can transact at any of the country. Registration and deposits are free and most other transactions are priced based on a tiered structure to allow even the poorest users to be able to use the system at a reasonable cost. It allows for relatively small transaction (IFC, 2019). The company’s ability to accommodate customers from all strata, including those at the bottom of the pyramid makes M-PESA more relevant to inclusive innovation discourse.

3. Policy and Research Agenda for Africa

Achieving level 6 as indicated above may require the involvement of many actors. Apart from the innovations introduced by multinational corporations, many innovations and their creators suffer from lack of exposure, financial assistance, institutional support and linkages with knowledge institutions and infrastructure to improve and scale-up and scale-out their innovations. For this reason, many inclusive innovations, especially those developed in local contexts do not leave the niches in which they were created (Gupta, 2010). Cozzens and Sutz (2014) made recommendations that may be applicable to developing an agenda for Africa. The activities that lead to new products, processes and services are based on traditional knowledge. Therefore policy and research initiative must focus on what marginalised groups do to innovate. Policy interventions in this regard may entail developing a database of such innovations for possible scaling-up (OECD, 2013; Gupta 2006; 2012). The dynamics among the actors in the innovation system for inclusive innovation should also be understood and given due attention. Research can be conducted on the workings of the innovation system to see where important actors fail to interact. Interactions among actors are a fundamental requirement for the successful development and diffusion of inclusive innovations (Lundvall and Lema, 2014). The political, social, cultural, and economic landscape outcomes of the adoption of the innovation should be carefully studied. If inclusive innovations are to be widely adopted, structural and institutional changes which require political backing may be required.

Appropriate policy mechanisms will play key roles in creating a favourable environment for inclusive innovations to be developed and scaled-up. There must be the effective leveraging of inclusive innovations to tackle Africa's development challenges more efficiently (OECD, 2015). The education curriculum should be reviewed to address economic realities of Africa. Efforts of research institutions may be directed towards inclusive innovation. Technical/consultancy firms may provide relevant services to firms dealing in inclusive products or services. Network institutions, such as technology parks and business accelerators can be established to help transform prototypes of inclusive innovations to business applications or innovative government programs (Dahlman et al., 2014).

4. Conclusion

If Africa is to forge its own development trajectory, an agenda to pursue the development of inclusive innovations may be necessary. These innovations can be used to effectively and immediately address developmental challenges faced on the continent and shortcomings of conventional technological innovations

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Integrating Phytodisinfectants with Sand Filter Device for Inclusive Community Household Water Treatment in Rural Africa

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Abstract

An evaluation and installation of an integrated low-tech Phytocoagulant-sand filter device for household water and waste water purification akin to rural communities in Africa, using bacterial culture tests, total solids, and turbidity amongst others is presented. Demonstration using a hundred litres of very turbid water (130.3 NTU) was pretreated with 100 seeds of Moringa oleifera and further filtered through a sand filter drum (120 litres carrying capacity) made of fine, coarse sand, charcoal and gravel. The mean total aerobic mesophilic bacterial counts, E coli, coliform, pseudomonas, and yeast counts, as well as turbidity of untreated water drastically reduced to WHO acceptable standards for potable water. The results indicated that the mean values of the same parameters for sand filtered pond water alone was significantly lower than the corresponding mean values obtained for Moringa oleifera treated pond water. From the findings of this study, we moved on to build capacities for communities in North West Region of Cameroon, through training at the Cathedral Parish, Big Mankon, Bamenda with more than a hundred participants. Four household water filters were installed during the trainings and have been in used for the past 6 years.

Key words: *Phytodisinfectants, Phytocoagulants, Moringa, Coliform, E coli, Bacteria, Turbidity, Sand filter, drum, purification.*

1. Introduction

Water scarcity is a nagging problem in the developing countries, especially in rural, semi-urban and even urban areas in these countries. Water management has become a global phenomenon. The beginning of the 21st century has experienced heightened awareness on ecological matters.

Humankind has fully come to terms with the rapid urbanization and population growth that is invariably accompanied by adverse environmental problems. There are a number of natural, social and economic activities that affect water quality and availability.

This work is not intended now to delve elaborately on this which enormous literature elsewhere holds, but it may be timely to comment that there are some water bodies that are naturally defective due to the geology of the area, and this is quite present in Africa. There are also natural and artificial water bodies like ponds that contain a lot of nutrients and unacceptable for consumption, yet in many villages across Africa, the unacceptable water still remains a prized possession.

A number of natural and political disasters in Africa have generated a social quagmire and a scandal to the scientific world, as clean water and other embarrassing environmental challenges abound. Furthermore, Conflict prone areas around Africa like the Dafur region of Sudan, DR Congo, parts of North West and South regions of Cameroon, to name a few, experience acute water crises. We need not stretch too far, for it has been estimated that 125 litres of water (potable) is required per person per day, yet, many households across the 55 Member States in Africa cannot actually boast of 25 litres of clean water per person per day. In tandem with this, water purification technologies would have to be reviewed in terms of its simplicity, accessibility (cost) and efficiency.

The search for simple, reliable and effective method of water treatment led to the use of plant materials including seeds of *Moringa oleifera* (Eilert, 1978) and Yongabi (2004). Standard methods for the treatment of water include coagulation, flocculation, sedimentation and disinfection. These methods are often inappropriate due to prohibitive cost and low availability of chemical coagulants and disinfectants. Dosage and technique poses some local challenges, and for this reasons efforts to establish appropriate chlorination techniques for wells in rural communities is imperative (Sam Godfrey, 2003) and Yongabi et al., (2011).

Regrettably, the available technologies in present day do appear complex and still expensive. No doubt, despite tremendous awareness campaign during the water and sanitation decade of 1981-1990, water and sanitation problems today still remain a major task to reckon with. If the Sustainable Development Goals Nos 2 and 3 in addressing the water and sanitation sector are something to go by, then the need to focus on integrated low cost water purification systems at grassroots bringing in innovation that encircles all members of the community stands unequivocal.

For communities perpetually with potable water, we may want to pause for a while to reflect on how is the water treated, even if the high cost is ever affordable, is the treatment regime in harmony with nature? Are there some side effects conceivable?

Nature, though sometimes harsh is still kind and tender, maybe we fail to get her echoes. Certainly we need an “Adam and Eve water purification type of technology”. Unfortunately, our

flickers of understanding in the way natural systems function erodes our confidence and creates an absurdity about natural systems in favour of the mechanical / chemical systems. The ball has been rolling, the bucket method of water purification using Moringa oleifera by Folkard and Sutherland is a case in point (Fuglie, 1999), and Folkard *et al.*, (2000) and Yongabi *et al*., (2011) although that generates less quantity of fairly pure water perhaps on a daily basis. The integration of moringa pretreated cum sand filtered water offers a unique opportunity that overcomes the shortfalls of both techniques. The idea of the sand filter stems from spring water. Spring water is the purest form of water in nature as the water filters through different geological beds.

In this report, an evaluation of the potentials of Integrating Phytocoagulant and sand filtered treated water is presented alongside installations using a community capacity building for more than a 100 participants in Cameroon.

2. Material and Methods

Pretreatment of surface (pond) water with *Moringa oleifera* seeds.

Figure 1
Drum for pretreatment of water with Biocoagulants (e.g. Moringa oleifera, lam)

Figure 2
Moringa seeds

Mature seeds of *Moringa oleifera* were obtained around homes in Bauchi (see figure 2) 100 seeds were deshelled and pulverized in clean mortar using a pestle. The powder (from 100 seeds) was sprinkled onto 100 litres of the dirty pond water in a 150 litre capacity drum (see figure 1) and stirred using a clean wood stirrer and the set up allowed to sit for 30 minutes. It was then filtered off using a muslin sack cloth and the filtered water was then passed through a sand filter drum (see figure 3).

2.1. The Sand Filter Drum

Figure 3
Sand filter drum
Drum 1 (left) – sand filter media
Drum 2 (right) – collection /storage of filtered water

Figure 4
Activated carbons from shells of Coco nucifera (Coconut) and Leo carpus spp

The materials used in the construction of the sand filter were locally gotten at a river bed and included; low strong (150 litre carrying capacity) drum (plastic), 1 ½ yards of hose, four clips, three nipples, strainer or sieve, sharp river sand (coarse and fine), charcoal and gravel. All these materials (sand, gravel and charcoal) were carefully washed and rinsed repeatedly in clean water. The laying of the materials in the drum was done in the order; laying of perforated hose connected to the collector tank, then a layer of gravel, followed by a layer of charcoal, then coarse sand (2mm in size) and two layers of fine sand (0.15 - 0.30mm size) on top (see figure 4). A test trial was carried out by flushing the set up repeated with clean water. The moringa pretreated water was then passed through the system. The filtered water was collected in drum 2 and samples taken for analyses. Three pond water samples were collected and subjected to all these treatments.

2.2. Study Site

The pond water (surface) was located in Bamenda metropolis, Cameroon (see figure 5). The pond water is shallow, very turbid and during the dry season, people sometimes fetch the water for household chores, stray animals, cows drink from the source.

Figure 5
Pond (Surface water): Where samples were collected for the study.

2.3. PH

The PH of the water samples before and after treatment with biocoagulants and sand filter was measured using a PH meter model PH 1-125. The electrodes of the PH meter were standardized by calibrating in acidic and basic buffers raised on distilled water. PH was taken by inserting the electrodes into test tubes containing wastewater samples and PH read off from the meter screen. The values obtained were consistent with values from HACH DR 2000.

2.4. Temperature

Temperature was read off directly from the PH meter.
Total solids and Turbidity were analyzed using HACH protocols. The HACH (model 44600) DR 2000 was used for the analysis. The analysis was conducted at the WATSAN laboratory, Bauchi.

2.5. Microbial Analysis and Criteria for Selection of Tests

The microbial analysis was carried out according to protocols specified by Burns (1974), APHA (1983) and APHA and WEF (1995). The MPN technique was avoided due to the fact that it is time consuming, while the membrane filter technique was not considered because of certain limitations such as lack of facility for coliform counts and Total aerobic bacterial counts etc, while the presumptive coliform test is also time consuming as limited in other microbial parameters.A range of tests such as total aerobic mesophilic bacterial counts, pseudomonas aeruginosa counts, as well as yeast counts were considered in addition to the traditional coliform and faecal coliform tests to explore the possibility of taking care of viable but non culturable bacterial. Besides, the traditional indicator tests do not always correlate well with certain groups

of pathogens such as *Helicobacter pylori* and *Aeromonas* spp and it is worthwhile considering this, especially in assessing the potential of newly constructed systems for water purification.

2.6 Culture Test

Three samples from very dirty pond (surface) water were collected sterile Maccathney bottles. One ml of the samples each was serially diluted with distilled water (9mls) threefold; i.e. up to 10^{-3} and one ml of each diluent of 10^{-1} and 10^{-3} were plated aseptically onto nutrient agar for total aerobic mesophilic bacterial and pseudomonas counts, MacConkey agar for Total coliform and Eosin Ethylene Blue agar for *Escherichia coli* counts and potato dextrose agar for yeast/fungi counts.

The whole set ups were incubated at 37^0C for 24 hours, and plates were read off following standard microbiological procedures. The bacterial counts were enumerated using Gallemp colony counter and recorded accordingly while the yeast and *pseudomonas* colonies were picked, stained using methylene blue and gram stain respectively. The average counts from 10^{-1} and 10^{-3} dilutions were recorded.

3. Results and Discussion

The results are presented in Tables 1 to 5 and figs I to IV. The findings showed conclusively that combining *Moringa oleifera* seeds with the sand filter outfit, one can recover very dirty water for consumption. The raw data obtained from pond water showed a very high Total aerobic bacterial population and high faecal indicator bacteria suggesting the presence of pathogens. Normally, surface water is not usually consumed in Bamenda, Cameroon but during the dry season when there is acute water shortage; people fetch such water for other non-potable domestic uses. These include, laundry, washing of dishes and in some outskirts- in rural places, when the situation grows deplorable, the people treat such water with Alum, boil and use if for drinking.

The high *E coli* (5100 cfu/ml) and coliform counts (7300 cfu/ml) shows how unsafe the pond water is for use in any activity. The use of the pond water for bathing could expose one to skin diseases especially if one has wounds or scratches on the skin. The presence and fairly high pseudomonas aeruginosa counts (115) supports this. Generally, surface water in Bauchi state is heavily contaminated and this holds true for most streams across Nigeria. This is as a result of a lot of human activities going on in the vicinity of these water bodies. The mean bacterial counts of the pond water when treated with *Moringa oleifera* seeds showed drastic reduction in bacterial counts from Too numerous to count to 394 colony forming units per millilitre. This falls within the WHO range (Tables 5, figure 2). However, despite a drastic reduction of *E coli* and coliform counts (Table 5) of the pond water when treated with *Moringa* seed powder, the water cannot still be consumed as suggested by the values, which are far off from the WHO recommended values.

This however, suggests another round of treatment, without refuting the efficiency of moringa as a coagulant and disinfectant. Moreover, water treated with moringa cannot last for more 48

hours without bacterial re-growth. It was in consideration of this that the integration of a sand filter system to moringa treated water was carried out. When this was done, the total aerobic mesophilic bacterial counts reduced to 8 cfu/ml, *E coli* counts reduced to 0.3 cfu/ml while coliform counts to 5.3 cfu/ml. The values were found to be in the WHO standard values for potable water (Table 5, figure 1, 2, 3, 4).

The turbidity, as well was drastically reduced within the WHO acceptable level. The results equally indicated that the sand filter is more efficient in purifying water that the seed powder of moringa oleifera (Table 3). This is attributed to the fact that sand filter drum is made up of a number of layers of materials with different textures and filtering capacity; fine sand, coarse sand, charcoal and gravel. *Moringa oleifera* is rich in nutrients which extracts into the water and later serves as a substrate for bacterial re-growth. Water filtered through the sand filter stores far longer than with *Moringa* treated water.

Despite the comparatively better water treatment potentials of the sand filter. It cannot purify very dirty pond water (the kind of water sample used in this study, Table 5) at one stretch. Without doubts, the sand filter drum has been very efficient in treating well water, borehole, and deep stream water. The CARUDEP (Catholic Arch diocesan Rural Development Programme in Jos, Plateau State of Nigeria) as well as the Phytobiotechnology Research Foundation Cameroon, have been installing sand filter drums in many rural communities in Jos, Nigeria and Cameroon respectively, for treating various sources of water. In cases where the water is very turbid (muddy water), they would advise the rural people to either strain the water using a sack cloth or keep in the sun for sedimentation to take place before filtering through the sand filter.

This has worked well, but the option of a pretreatment with biocoagulants particularly seeds of *Moringa oleifera* has not been done. It was in view of this that the need arose to evaluate the potentials of an Integrated Moringa/sand filter drum for purifying all sorts of available water for consumption. The analyses has shown that pond water can be treated effectively using an integrated moringa/sand filter drum. In addition, the system can provide a greater volume of treated water at household than with the Moringa bucket system reported by Folkard and Sutherland. (Fuglie, 1999).

4. Conclusion / Lessons Learnt so far for Continued Inclusive Community Scale Up

The attending benefits are enormous; the short falls of the two systems are dissolved, greater volume of treated water can store longer, any dirty water can be treated and consumed. The techniques are accommodating and the materials needed are cheap, almost all naturally available. From the trainings carried out, handicapped persons, women and children, community chiefs, religious leaders are able to carry out installations without technical setbacks.

The Phytobiotechnology Research centre, Cameroon, has begun the installation of this system in rural/semi-urban communities in Cameroon and some parts of Imo State in Nigeria, while studies are underway using other natural coagulants as well.

To cap it all, the development and integration of a low cost sand filter devices making use of raw materials abundant in the rural communities, such as *moringa, jatropha* and sand as well as local clay pots for household water purification could catalyse small scale water business and improved sanitation and decimated episodes of water borne diseases in Africa in general. The treated water can also be packaged and hawked, and that could generate some extra earning as well. It remains to say that refugees and people in disaster prone areas could have this type of systems installed easily.

Parameter	Surface water (pond) sample 1	Surface water (pond) sample 2	Surface water pond samples 3	Mean values (X)
Temperature (O^0C)	27.0	26.0	27.1	27.0
PH	7.6	7.5	7.6	7.6
Turbidity (NTU)	130.3	130.1	130.3	130.2
Total solids mg/dm^3	466.0	466.0	466.0	466.0
Total aerobic mesophilic bacterial counts (cfu/ml)	TNTC	TNTC	TNTC	TNTC
Escherichia coli counts (cfu/ml)	5200	4900	5200	5100
Coliform counts (cfu/ml)	7300	7300	7300	7300
Yeast counts (cfu/ml)	2500	2520	2,338	2452.7
Pseudomonas counts (cfu/ml)	1220	900	1,118	1151

Table 1 Physico-chemical and Microbial Assessment of Pond (Surface) Water before Purification.

TNTC – Too Numerous To Count
* Water source, people use the water for other domestic chore
- Stray animals (cows) drink from the source sporadic
- Analysis was done in the peak of dry season, water shortages experienced.

Parameter	Surface water (pond) sample 1	Surface water (pond) sample 2	Surface water (pond) sample 3	Mean values (X)
Temperature	27.0	27.0	27.0	27.0
PH	7.0	7.0	7.0	7.0
Turbidity (NTU)	30.5	30.9	30.9	30.8
Total solids mg/ml	352	352	352	352.0
Total aerobic mesophilic bacterial counts (cfu/ml)	393 *	395	352	352.0
Escherichia coli counts (cfu/ml)	574	574	570	572.7
Coliform counts (cfu/ml)	438	439	436	437.7
Yeast counts (cfu/ml)	755	755	758	756.0
Pseudomonas counts (cfu/ml)	156	151	155	154.0

Table 2 Physico-chemical and Microbial Assessment of Pond (Surface) Water after Pretreatment with Moringa Oleifera (Lam) Seed Powder.

* Larger colonies with butter-like consistency.

Parameter	Surface water (pond) sample 1	Surface water (pond) sample 2	Surface water (pond) sample 3	Mean values (X)
Temperature (0^0C)	27.1	27.1	27.1	27.1
PH	7.6	7.6	7.6	7.6
Turbidity (NTU)	24	22	22	22.7
Total solids mg/dm^3	327	327	327	327
Total aerobic Mesophilic bacterial counts (cfu/ml)	188	192	189	189.7
Escherichia coli counts (cfu/ml)	13	15	13	13.7
Coliform counts (cfu/ml)	15	17	15	15.7
Yeast counts (cfu/ml)	23	23	25	23.7
Pseudomonas counts (cfu/ml)	10	12	15	12.3

Table 3 Physico-chemical and Microbial Assessment of Pond (Surface) Water after Purification with Sand Filter Drum.

Parameter	Surface water (pond) sample 1	Surface water (pond) sample 2	Surface water (pond) sample 3	Mean values (X)
Temperature	27.1	27.1	27.1	27.1
PH	7.6	7.6	7.6	7.6
Turbidity (NTU)	4.9	4.6	4.9.9	4.8
Total solids (mg/ml)	297	300	297	298
Total aerobic Mesophilic bacterial counts (cfu/ml)	10	7	7	8
Escherichia coli counts (cfu/ml)	0	1	0	0.3
Coliform counts (cfu/ml)	5	7	5	5.3
Yeast counts (cfu/ml)	10	11	7	9.3
Pseudomonas counts (cfu/ml)	3	4	4	3

Table 4 Physico-chemical and Microbial Assessment of Pond (Surface) Water after a combine Treatment with Moringa Oleifera Seed Powder and Sand Filter.

Parameter	Untreated pond/surface water (X)	Treatment with Moringa oleifera (X)	Treatment with sand filter drum (X)	Combine Moringa sand filter drum	WHO values (Ranges)
Temperature (0C)	27.0	27.0	27.1	27.1	-
PH	7.6	7.0	7.6	7.6	6.8 – 8.5 (9.2)
Turbidity (NTU)	130.2	30.8	22.7	4.5	0 – 5 (25)
Total solids (mg/dm^3)	466.0	352.0	327	298	500 (1,500)
Total aerobic Mesophilc bacterial counts (cfu/ml)	TNTC	394.0	189.7	8	0 - 500
Escherichia coli counts (cfu/ml)	5100	572.7	13.7	0.3	0 – 1
Coliform counts (cfu/ml)	7300	437.7	15.7	5.3	0 – 10
Yeast counts (cfu/ml)	24.52.7	756.0	23.7	9.3	-
Pseudomonas counts (cfu/ml)	151	154.0	12.3	3	-

Table 5 Comparing Mean Values for Untreated, Moringa Treated, Sand Filter Treated and Moringa-Sand Filtered Ponds (Surface) Water.

TNTC – Too numerous to count
Values in brackets indicate maximum permissible limit.

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LANDPKS Mobile App as a Tool for Bridging Climate Information Gaps for Improved Agricultural Productivity, Land Use Planning and Climate Change Resilience

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Abstract

Agriculture is increasingly becoming more knowledge-intensive and innovative oriented though faced with a myriad of challenges ranging from climate variability and increasing competition for use of land and water resources. Having access to timely, accurate information that is tailored to specific locations and conditions is critical in helping farmers make the most of their resources in often changing circumstances. With improved technology and expanding telecommunication and internet access in Africa, chances of achieving these are continuously improving. However, achieving this is being derailed by slow adoption, slow of infrastructure development and lack of policy framework in most African countries. Different tools have been and are still being developed to ease access to information including climate and market information. *LandPKS* is one such tool that is freely accessible and provides instantaneous climate and soil information by use of a smartphone. This tool has been used in various countries by farmers, extension agents, land use planners and policy makers and the results have been impactful. There is need to upscale the use of *LandPKS* given its potential to transform Agriculture. However, this requires investment in the required infrastructure as well as the policy framework which is lacking.

Key words: *Climate Change, Land-use, Resilience, Productivity, Planning and Technology, LandPKS*

1. Introduction

Africa's continued agricultural growth over the last couple of years has come from land expansion rather than increased productivity (Fuglie and Rada, 2013). However, available agricultural lands are rapidly diminishing due to urbanization, while soil fertility continues to decline due to land degradation, poor farming practices, soil erosion, and the impact of climate change (Ozor et. al., 2015). There are growing concerns to rethink current land use mechanisms, and devise innovative strategies that ensure that available land under agricultural production becomes more productive and sustainable. Efforts to achieve increased food productivity will come not only from agricultural intensification and land conversion production strategies but will require use of innovative technologies that provide accurate, robust, and timely information and knowledge of land potential to support decision making at the various scales of the agricultural system (Ozor et. al., 2015).

Technology has played a significant role in developing the agricultural sector more specifically through the green revolution; use of machinery for improved yields, modern transportation has made it easy for farmers to transport their produce to the markets, while cooling facilities have enabled farmers to properly store their produce to avoid post-harvest losses. By empowering farmers with information via access to modern technology, they will be in a better position to innovate and effectively change the potential of their land through robust farm management practices that enhance productivity as well as increase crop resilience to changing climatic conditions. Additionally, the development of mobile apps have helped farmers solve a wide range of problems on their farm lands. All these factors which are attributed to technology have helped improved agricultural productivity.

A myriad of factors have been attributed to low agricultural productivity and reduced resilience and adaptation to climate change. Needless to say, lack thereof of information systems has been an obstacle to efficient dissemination and uptake of technological innovations and access to basic production and market information (World Bank, 2007). This involves a combined use of both traditional and new technologies for better efficiencies in information processing analysis and dissemination (Litondo and Ntale, 2013).

Advances in mobile technological application are paving the way for the development of new innovative tools that can facilitate the integration of information and knowledge, using local knowledge and crowdsourcing technologies in effective decision-making on land management strategies for improved agricultural production. The rapid expansion of internet accessibility through mobile phone networks together with simple mobile applications provides new opportunities to connect farmers, extension workers, development planners, and policymakers with site-specific knowledge and information on land potentials. Leveraging the emerging technological trend, the Land-Potential Knowledge System (*LandPKS*) presents a suite of mobile apps that allows individuals and organizations to use a mobile phone to determine land potential at a specific location based on local and global knowledge and information. One such app is the *LandInfo* mobile App Technology. This is a community-driven initiative that enables users to instantaneously access climatic and soil information and interpret them in the context of local

conditions and values, including crop preferences for specific soils. The app development was informed by the lack of easily accessible, timely and accurate climatic and soil information by the community of small-scale farmers and pastoralists especially in Africa to inform decision-making. This mobile app has made it possible for users to target investments on land for specific purposes such as crop choices for specific soils based on prevailing climate. This app has also helped pastoralist to make decisions on how to use their pasturelands in light of the prevailing climatic conditions. With knowledge on annual average rainfall and temperature distributions, aridity index, soil types, and water retention capacity among other features provided by the *LandInfo* mobile App, farmers are able to plan their farming enterprises adequately to avoid losses caused by climate variability and hence improve productivity and resilience.

2. Methodology

The *LandPKS* project was designed to directly support land management decisions by farmers, ranchers, and pastoralists; inform land use planning and investments in land management by governments, non-governmental and overseas development assistant organizations. The *LandPKS* development draws enormous data support and collaborative effort from the Food and Agriculture Organization (FAO); Global Soil Map; the International Soil Reference and Information Center (ISRIC), Conservation International's Vital Signs Project; former Kenya Agricultural Research Institute (KARI) now known as Kenya Agriculture and Livestock Research Organization (KALRO); African Soil Information System (ASIS); European Environment Agency (EEA), including Eye on Earth; and several Consultative Group on International Agricultural Research (CGIAR) Centres; as well as a number of sustainable land management knowledge systems such as World Overview of Conservation Approaches and Technologies (WOCAT). These partners provided research data, technical expertise, research sites and validated the products throughout the development process. The community members working with the different implementing partners were continuously involved in the development process by providing information both historical and current. They were also part of the validation teams selected in the research sites.

The *LandPKS* was developed and implemented through a phased, modular approach designed to complement, rather than replace, new and existing land evaluation, database development, and soil mapping initiatives, as well as government extension efforts and local and international development projects (Fig. 1). Characteristics unique to *LandPKS* include the ability to provide site-specific information based on simple soil descriptions, to effectively integrate local and scientific knowledge through expert systems that assess multiple sources of qualitative and quantitative knowledge and information, and to provide an interactive self-learning platform that simultaneously collects and shares knowledge and information among a broad range of users. This kind of approach allowed stakeholders to apply early versions of the system to make basic determinations about land potential; maximized opportunities for them to contribute knowledge and information to the system, including providing instant feedback on initial determinations; and ensured that the system is sufficiently flexible and dynamic to take advantage of and contribute to future tools, technologies, and information and knowledge sources (Herrick et. al., 2013).

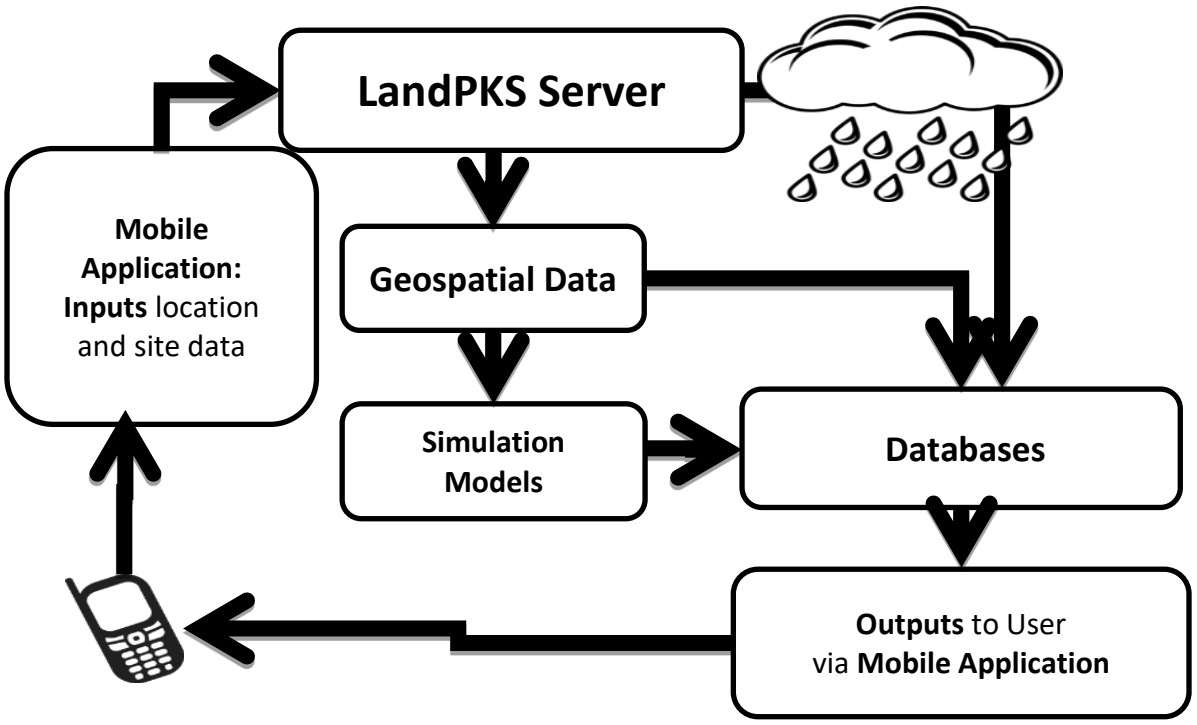

Figure 1: Conceptual Framework for LandPKS

African Technology Policy Studies Network (ATPS) and its partners piloted the *LandInfo* mobile app in Kenya and Namibia, and is being scaled-up for adoption in Kenya, Malawi, Nigeria, Tanzania, Ethiopia among other African countries through intensified sensitisation and capacity building programmes for lead farmers and extension agents on the use of *LandInfo* mobile app. Plans are underway to conduct initial Training of Trainers (ToT) training in Cameroon and Tunisia through the support of African Development Bank (AfDB) which funded the Bridging climate information gaps for climate informed decision making project in selected African countries (Cameroon, Kenya, Malawi, Nigeria and Tunisia). Other trainings in Kenya were supported by African Agricultural Advisory Services (AFAAS).

Secondary data that entailed desk research and content review of scientific literature including peer-reviewed articles, research papers and review papers, grey literature such as policy documents, strategy and actions plans, project reports, consultancy report and donor reports were used in this study.

3. Results and Discussion

This study was informed by the rapid expansion of internet accessibility through mobile phone networks. Simple mobile applications have been able to provide new opportunities to connect farmers, extension workers, development planners, and policymakers with site-specific knowledge and information on land potentials. Leveraging the emerging trends in technology,

the *LandPKS* project presents a suite of mobile apps that allows individuals and organizations to use a mobile phone to determine land potential at a specific location based on local and global knowledge and information (Herrick et. al., 2013).

3.1 Mobile Phone and Internet Connectivity

Studies in many African countries show that mobile phone connectivity has been increasing over the years. According to Global System Mobile Association (GSMA) report 2018, Sub-Saharan Africa's GSMA Mobile Connectivity Index aggregate score has consistently improved over the last three years, reaching 38.6 in 2017 (Fig. 2). This was mostly driven by notable improvements in the affordability and content enablers. However, it lags behind other regions by a considerable margin (Fig. 2), highlighting the need for all stakeholders – governments and regulators, mobile operators and other ecosystem players, and development agencies – to work together to enhance digital inclusion in the region. The GSMA Mobile Connectivity Index measures digital inclusion in 163 countries across the world, including 37 countries in Sub-Saharan Africa, against four key enablers – infrastructure, affordability, consumer readiness, and content. This helps to demonstrate the impact of the enablers on digital inclusion, and supports the efforts of the mobile industry and other stakeholders to deliver on the ambition of universal internet connectivity (GSMA, 2018).

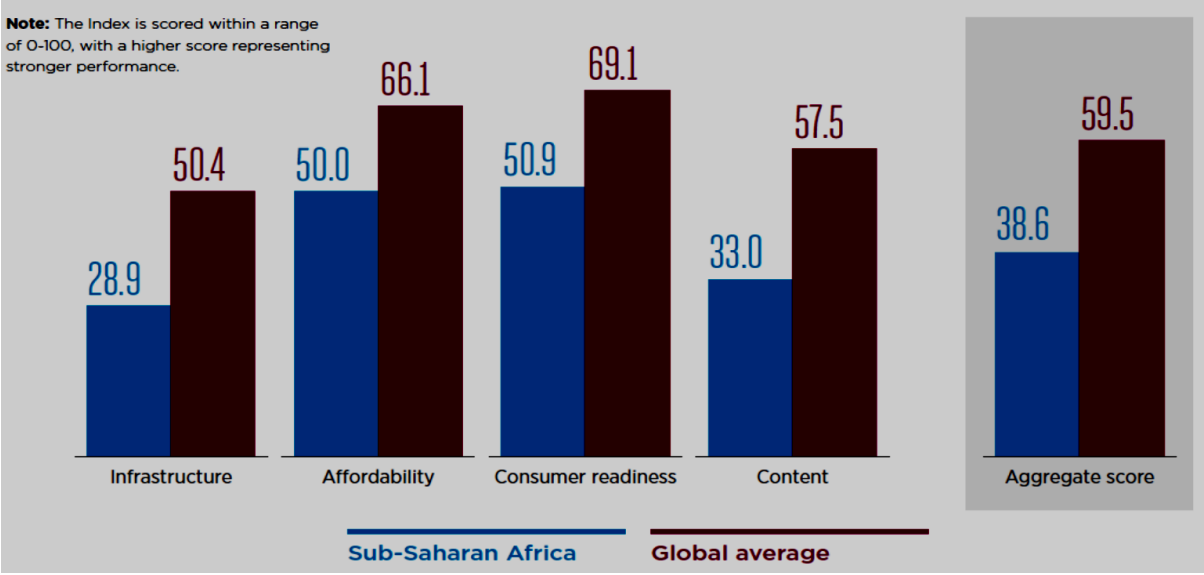

Figure 2: GSMA Mobile Phone Connectivity Index

Mobile subscriber penetration in Sub-Saharan Africa stood at 44% at the end of 2017, still well below the global average of 66%. The subscriber base in the region totalled 444 million, equivalent to around 9% of subscribers globally (GSMA, 2018). The regional subscriber base will grow at a Compound Annual Growth Rate (CAGR) of 4.8% for the period 2017–2022, more than double the global growth rate over the same period. The penetration rate is forecast to reach the 50% level by the end of 2023, and 52% by 2025 (GSMA, 2018).

Huawei's 2018 report entitled 'Tap into New Growth with Intelligent Connectivity' has awarded Kenya a global connectivity index (GCI) of 29, making it one of the top countries in Sub-Saharan Africa in installing broadband networks and investing in various enabling technologies (Mbogo, 2018). Other Sub-Saharan Africa countries with a GCI score of 29 include Ghana, Nigeria, Botswana, and Namibia.
In Africa, Egypt is leading with a GCI score of 34 making it one of the top movers in 2018's index. Egypt's GCI score grew by one point in 2018 thanks to efforts in boosting the percentage of people using smartphones, ensuring that fixed and mobile broadband is more accessible and more affordable, and increasing internet access in private and public sectors (Mbogo, 2018).

African countries are still in the starters cluster as they struggle to keep up with the front runners and adopters and as the digital divide continues to expand. According to the Huawei report, starters should increase their annual investment in connectivity, broadband coverage, and data centres by 13 per cent. In addition, these countries are advised to focus on AI-driven growth as they prepare for the new cycle of growth in the digital economy (Mbogo, 2018). The report also recommends starters to boost 4G coverage, increase internet use, boost the use of smartphones, concentrate on e-commerce and cloud, and educate the workforce.

3.2 Smartphone Adoption and Agricultural Productivity

Smartphone adoption continues to see rapid growth in Sub-Saharan Africa, albeit from a relatively low base and despite affordability challenges. The total number of smartphone connections stood at 250 million at the end of 2017, equivalent to a third of the total connections base. The adoption rate will double by 2025 to reach two-thirds of total connections, equivalent to an installed base of around 690 million (GSMA, 2018). Rapid growth in the number of smartphones in the region means the adoption gap compared to the developing market average will close materially over the forecast period.

A review of mobile phone services for supporting agricultural knowledge management and decision making has shown that leveraging mobile phone application for agricultural production can engender highly beneficial outcomes from the local to national, regional and global scales. These outcomes include among other things enhanced land and crop productivity, appropriate crop and land production choices, enhanced value-chain development, access to markets, and information on commodity prices. A report by Vodafone identified twelve Information Communication Technology (ICT) based opportunities that has the potential to deliver approximately 75% of agricultural income from access to financial services, markets, improving data visibility and agricultural information via mobile phone usage (Kirk et. al., 2011). These opportunities include: mobile payment system, micro-insurance system, micro- lending platform; mobile information platform, farmer helpline, smart logistics, traceability and tracking system, mobile management of supplier networks, mobile management of distribution networks, agricultural trading platform, agricultural tendering platform and agricultural bartering platform.
We fully recognize that in many cases the ability to sustainably increase agricultural production, climate change resilience building and biodiversity conservation and to address other objectives is not limited by knowledge and information about climate information or biophysical land

potential. Access to markets, prices for agricultural products and inputs (which sometimes may be accessible on phone), social and political instability, and local food preferences frequently constrain land use decisions (Herrick et. al., 2013). This is true in many and perhaps most cases. However, an understanding of land potential is necessary to select the most sustainably productive land use or uses and management systems, and that this understanding can also be used to select from a range of options that is already limited by non-biophysical factors (Herrick et. al., 2013). By starting with the biophysical potential of the land, we provide a foundation for integrating other factors, such as food prices. Socioeconomic factors will be integrated as *LandPKS* evolves, either by linking to other programs, or as an integral part of the system itself (Herrick et. al., 2013).

3.3 Deployment of LandInfo mobile App in Africa

Field piloting of the *LandPKS* system in North and central Kenya and North- eastern Namibia has provided promising evidence of *LandInfo* and *LandCover* App viability to provide vital information for decision making on land potential, restorative and adaptive practices and resilience at local, national, regional, and global scales. Figure 3 shows the schematic chart for *LandPKS* system.

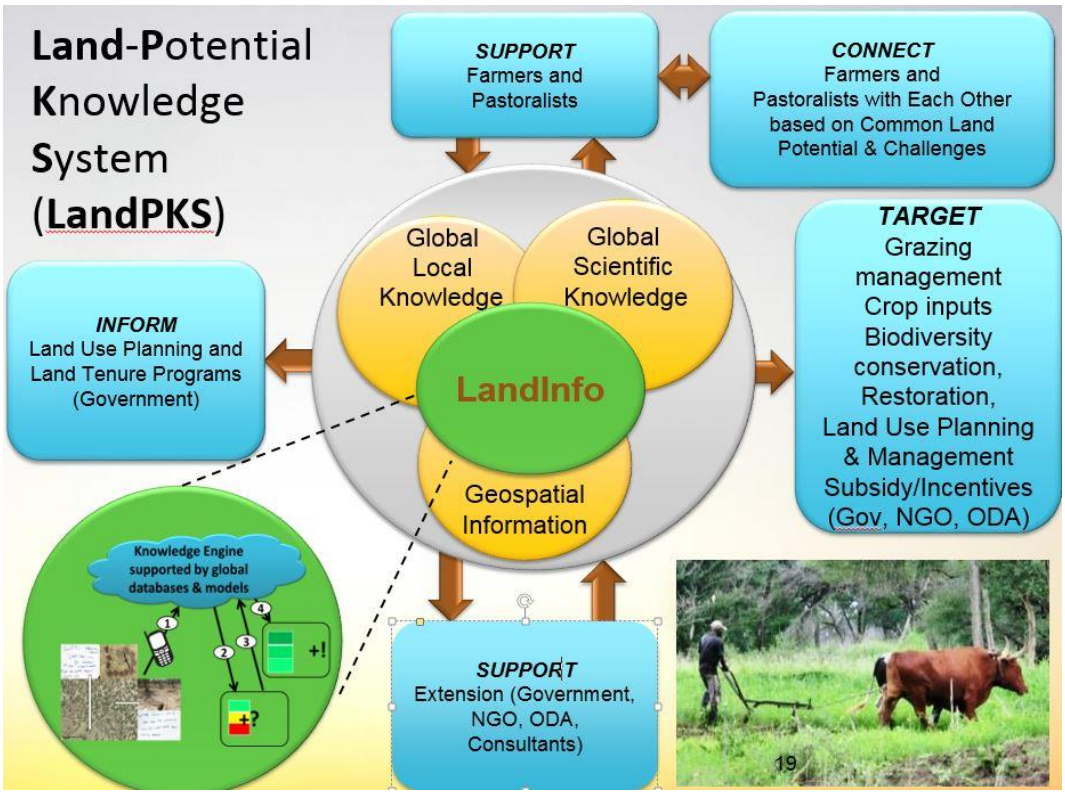

Figure 3: Schematic Chart for LandPKS

The *LandInfo* mobile app was then deployed in various counties in Kenya. This was preceded by a series of trainings conducted by ATPS. Over 5,000 people who consist of model farmers,

extension workers and land use planners have been reached with over 2,500 trained through the ToT trainings. In Malawi, 90 people were trained and over 200 reached. In Nigeria over 150 people were trained and another 300 were reached. Plans are under way to conduct two (2) more trainings in Cameroon and Tunisia. There is evidence that other ATPS partners are also promoting the use of this app but there is limited information as to how many people or countries they have covered. Figure 4 below shows some of the outputs of *LandInfo* mobile App deployed in Nsukka, Enugu State in Nigeria and Lilongwe in Malawi in 2018.

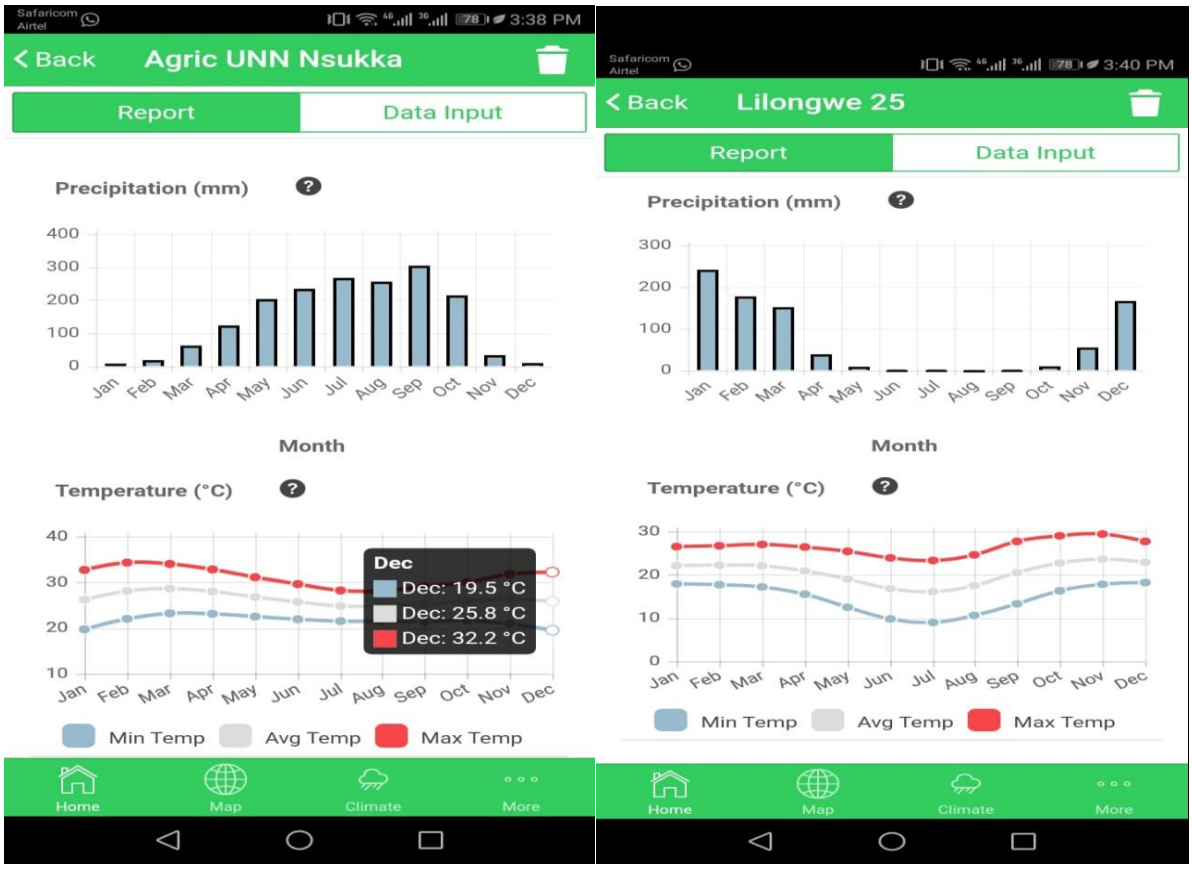

Figure 4: Sample Climate Outputs from LandInfo mobile App

There is overwhelming positive feedback from those who were trained and those using the mobile app for land use planning, decision making and as a tool for building climate change resilience. There is increasing demand across Africa to conduct more trainings and expose the African people to this important app which is freely accessible under the android and IOS platforms in google play store or apple store respectively. The ATPS is willing to heed their call and provide this service subject to availability of funds. The training reports for the ToT trainings already conducted can be found at https://atpsnet.org/projects/bridging-climate-information-gaps/ for trainings supported by AfDB and https://atpsnet.org/projects/landinfo-mobile/ for those supported by AFAAS.

ATPS has scooped two (2) climate information prizes in Kenya. The 2016 Wazo Prize and 2018 Tekeleza Prize were awarded to ATPS for its efforts in providing an innovative solution to access climate information in Kenya in a very competitively organized platform.

3.4 Policy Implications

As mobile operators edge towards full coverage of a more densely populated conurbations within the sub-Saharan region, the remaining unconnected populations are primarily located in rural areas where the economics of network rollout are more challenging. To extend connectivity to underserved areas and ensure long-term industry sustainability requires the establishment of relevant regulatory frameworks and investment-friendly policies to facilitate multi-year capex programmes. Two key policy enablers that can help support the continued growth of the mobile ecosystem are the formulation and implementation of the appropriate management framework, and tax reform to improve the affordability of mobile technology for consumers, especially those in low-income segments. Similarly, tax reform can enhance digital inclusion in the region, with positive knock-on effects for productivity and the wider economy.

Most African governments have been slow in passing laws that will provide guidance on the development and use of ICT infrastructure. Nigeria, for instance, relied on its ICT administered under three main policy documents: the National Mass Communication Policy of 1990, the National Telecommunications Policy of 2000, and the National Policy for Information Technology of 2000 (Macharia, 2014). On the other hand, Tunisia is one of the leading ICT countries. With an internet penetration rate of more than 41% in 2012, Tunisians are among the world's most active users of Twitter and Facebook, according to Internet World Stats. The country's internet infrastructure is also fairly modern, with two ground connections to Libya and Algeria and three undersea cables to Europe.

As with other regions, Africa also faces the threats posed by internet security and privacy issues. In its attempt to create enabling legislation, the African Union crafted the Convention on Cyber-Security (AUCC) in 2011 to provide legislation and guidance on the "organization of electronic transactions, protection of personal data, promotion of cyber security, e-governance and combatting cybercrime." The continental body is currently seeking ratification of the convention, but has met resistance from civil society organizations who feel the convention infringes on citizens' rights to freedom of expression and privacy. Some of its provisions will also make it difficult for internet service providers and online businesses to operate. While Africa's growth in mobile and internet access has been rising faster over the last decade than any other region of the world, the continent is still playing catch-up (Macharia, 2014). The continuing investment in infrastructure, dropping costs, rising incomes and demographics, however, will lead to a far greater growth over the next decade.

Using *LandPKS* to achieve sustainable agricultural development goals requires greater investments in networking, awareness creation, advocacy, and capacity building to promote transfer of this technology, its adoption and application and mainstreaming into local, national and regional agricultural/land policies. Highly important is the fact that, *LandPKS* application is

demand driven and affordable with the ability to reach the majority of target beneficiaries. The long-term impact and sustainability of *LandPKS* will principally rely on instituting flexible but strongly supportive policies, technological appropriateness, and the enabling environments for innovation.

The following policy strategies serve as sound considerations to guide the development, application and sustainability of *LandPKS* in supporting agricultural development, land use planning and building resilience to climate change:

3.4.1 Creation of an Enabling Environment for Innovation

Implementing the *LandPKS* technology as an agricultural development intervention at a broader scale requires favourable and flexible regulatory and policy environment that foster the growth and integration of ICT in development planning. Governments should offer incentives for the telecommunication sector to make mobile broadband service and smart phones affordable and widely accessible particularly in rural communities. Incentives may be in the form of tax holidays for smart mobile phone manufacturers, reduction of duty on mobile phones, and public-private partnership investment in telecommunication infrastructure. Governments must capitalize on the potential contributions of technologies such as *LandPKS* to improve agricultural productivity, yield and sustainable land management by implementing robust and appropriate measures that would translate these potentials into real benefits. A case example is in Nigeria where the Federal Ministry of Agriculture announced in 2012 their plans to procure ten million mobile phones, worth about N60 billion, from China and the US for free distribution to rural farmers across the country as part of the Ministry of Agriculture's e-Wallet project. Under the initiative, the Ministry officials would be able to educate, inform and disseminate information to farmers in the rural areas across the country on the latest and best agricultural practices, as well as the current prices of commodities in the market (Daily Trust, 2013). It will be interesting to evaluate the impact of such initiative on agricultural development in Nigeria.

3.4.2 Development of a National e-Agriculture Policy

As the role of mobile phone in agriculture deepens, African countries should as a matter of urgency formulate national e-Agriculture policy which would explore and outline the possibilities of leveraging mobile phone-enabled platforms to produce robust models/tools that deliver agricultural information services for effective decision making at various scales. Currently, many African countries have developed national e-health, e-governance, and e-education policy strategies but are yet to develop a national e-agriculture policy for the sector that contribute to the major part of their Gross Domestic Product (GDPs). Two countries, Ivory Coast and South Africa have so far taken the initiative to develop e-agriculture strategies in line with emerging global ICT trends (Lohento et. al., 2013). Setting in place a national e-agriculture strategy is an essential first step for any country planning on using ICTs for agriculture. While the need for e-agriculture strategies is acknowledged by many stakeholders, most countries have yet to adopt a strategic approach in making the best use of ICT developments in agriculture. E-agriculture strategies will help to rationalize both financial and human resources, and address holistically the ICT opportunities and challenges of the agricultural sector while generating new

revenues and improving the lives of people in rural communities. Fundamental to the success of this policy will be the involvement of stakeholders and political commitment with the necessary budget allocation for policy implementation, research, and training.

3.4.3 Supporting Mobile Service Infrastructure

The success of a wider coverage and use of mobile phone application in agriculture will partly depend on the combined effort of government and the private sector. The private sector continues to remain the engine of ICT growth in Africa. Effort by governments in African countries to improve ICT infrastructure remain minimal, however, there are some good initiatives by governments through the establishment of appropriate institutional arrangement to facilitate ICTs infrastructural development. A laudable example by the Rwandan government is the establishment of Rwanda Information Technology Authority (RITA) to implement the National Information and Communication Infrastructure (NICI) Plan. The plan specifically focuses on building an export-oriented ICT industry and to boost development through ICT use in sectors such as agriculture, education, health, etc.

3.4.4 Creation of More Awareness on *LandPKS* Technology

Mobile phone application in agriculture is gradually gaining momentum in African countries and *LandPKS* technology is a new innovative knowledge system that has the potential to turn the face of agriculture on the continent. Evidence has shown that creating awareness and access to information via mobile phones can contribute significantly to farmers' livelihood, yield and income. In the 2012 World Bank "Information and Communications for Development" report, farmer's income increased between 16.5% and 36% in Uganda and 10% in Ghana, following enhanced access to market information through mobile phones (World Bank, 2012). It is very important to create awareness about this technology and the potential it offers to the different user categories including policymakers, development planners, extension workers, pastoralists, and farmers among others. Only then can these stakeholders realize the potential of *LandPKS* technology and apply it accordingly in their respective areas of agricultural development systems. National awareness of the value and benefits of *LandPKS* technology may take time to realize, however, advocating and engaging stakeholders including government and development partners at the national level may create more visibility and provide incentives for higher adoption rate for the technology.

3.4.5 Strengthening of End-Users' Engagement from Onset

It is important for developers and investors of technological innovations to pay attention to investment in human capacity and end-users' participation in planning and design stages. Several years of agricultural development experience have shown the importance of engaging farmers and policymakers in new technology development projects from the beginning. Low technological uptake in Africa has been attributed to; lack of interest, and mistrust arising from low inclusion and lack of end user incorporation to identify user need and interests. As a long-term strategy towards integrating mobile phone application in development, effort to integrate information technology into education systems from the primary to tertiary levels should be strengthened. Establishing short training courses on emerging technologies and innovations, tailored to meet the needs of

beneficiaries such rural farmers will boost their confidence, enhance adoption and expose them to the era of technological advancement.

Conclusion

The rapid expansion of internet accessibility through mobile phone networks together with simple mobile applications and expert knowledge systems provide new opportunities to connect farmers, extension and development workers, and policymakers with site-specific knowledge and information. The amount of electronically available knowledge and information about land potential, including resilience, is also rapidly increasing through the efforts of a number of organizations throughout the world. The *LandPKS* leverages these emerging trends to connect land managers committed to sustainable land management with the most relevant and up-to-date knowledge and information available. The emerging role of ICTs in sustainable agriculture as facilitator and their transformative effects on social and economic development can no doubt be underestimated. The *LandPKS* technology provides a suite of mobile apps that would contribute significantly to unleashing the potential of lands for productive uses, and building resilience in societies in Africa.

The ubiquitous status of mobile phone technology and its application in core sectors of the developing countries' economy, in particular agriculture, presents both opportunities and challenges. Like other mobile technologies before it, *LandPKS* risks being subjected to inflated expectation. While there is optimism about the prospects of *LandPKS* to play an important role in sustainable land management, it is important to remain cautious about the multiple barriers that could impede practical implementation of *LandPKS* to benefit agriculture as well as help build resilience against climate change.

Highly essential to the success of implementation of *LandPKS* technology at a wider scale is to understand the obstacles for *LandPKS* application, acknowledging the limits, its capacity and relevant context within which *LandPKS* operates. In the longer term, it would be necessary to examine the extended benefit of *LandPKS* technology towards addressing social economic issues such as poverty alleviation, migration and conflicts. In such circumstances, the *LandPKS* technology may offer sustainable solutions for better decision making and in empowering farmers at the local and national levels.

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We would like to acknowledge the staff of ATPS for their dedication in promoting the use of *LandPKS* tool. Specifically, we appreciate the commitment of Ernest Acheampong for his role as a resource person in the various training workshops conducted across Africa. We also thank the funders, African Development Bank and African Forum for Agricultural Advisory Services. ATPS will also like to thank its partners and donors for their contribution in development of this App as well as their efforts in promoting it.

Acronyms and Abbreviations

AFAAS	African Agricultural Advisory Services

AfDB	African Development Bank
ASIS	African Soil Information System
ATPS	African Technology Policy Studies Network
AUCC	African Union crafted the Convention on Cyber-Security
CAGR	Compound Annual Growth Rate
CGIAR	Consultative Group on International Agricultural Research
EEA	European Environment Agency
FAO	Food and Agriculture Organization
GCI	Global Connectivity Index
GDP	Gross Domestic Product
GSMA	Global System Mobile Association
ICT	Information Communication Technology
ISRIC	International Soil Reference and Information Center
KALRO	Kenya Agriculture and Livestock Research Organization
KARI	Kenya Agricultural Research Institute
LandPKS	Land-Potential Knowledge System
NICI	National Information and Communication Infrastructure
RITA	Rwanda Information Technology Authority
ToT	Training of Trainers
WOCAT	World Overview of Conservation Approaches and Technologies

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Linking Industry Science and Technology: EABC Perspective of GDP in African Countries (A study of the Fastest Growing Economies in Africa)

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Abstract

East African Business Council is a legal body defined by the treaty of East Africa Countries legislature. Its general objective is to drive East Africa Community integration process through trade and investment, with a vision to create Borderless inter-trade within member states. The member states include Kenya, Uganda, Tanzania, Burundi, Rwanda and South Sudan. The EABC has numerous achievements including the Creation of a One Network Area for Uganda, Kenya, Rwanda and South Sudan and over 156 East African Standards harmonization. It also supports academia, Government and industries in Innovation, Science and Technology to improve trade. Research in the triple helix (Government, Industrial academia and innovation) shows that Africa's current economic growth rate is far too low as industrial growth has slowed since 1970. Poverty, hunger, poor education, ill-health, corruption and violence have been a big challenge, and several systems need to work together to address those shortcomings to enable economic growth on the Continent and change the lives of future generations positively. However, several government organs, sectors, and cooperation need to work in collaboration by funding for research and development, innovation in major sectors and industries. EABC addressed this by establishing countries in Africa with the highest collaboration with the triple helix to raise their GDP. An EABC study identified and analyzed 10 countries with the fastest growing economies in Africa by 2016 and sampled Kenya, Uganda, Tanzania and Rwanda for the study. The data was to identify the funding of the triple helix and its relationship with

economic growth. The study recommended more effective policies to strengthen the triple helix collaboration.

Key words: *EABC, EAC, National Innovation, collaboration, industries, triple helix*

1.0 Introduction: East African Business Council (EABC)

Being the regional apex body of Private Sector associations and corporates in the East Africa, East African Business Council (EABC) has a single purpose of driving the East African Community integration process through trade and investment. In collaboration with the public sector, the academia, East African Community (EAC), and the business community, the Council acts as the back bone to uproot economic potential by making possible that there is free access to markets, enhanced environment for trade and business competitiveness in all the member states. EABC leadership focuses on creating a reflecting inter trade within the East African Countries and global engagement.

The Council has a major vision of creating a Border-less East Africa for business and investment, driven by promoting sustainable Private Sector-driven growth with values of Transparency, Good Governance, Respect for the rule of law Equal opportunities and a diverse workforce. By 2016, the member states included Kenya, Tanzania, Uganda, Burundi, Rwanda and South Sudan. Its strength is added by strong bonding at regional, national, and sectoral Private Sector associations as well as Corporates in the EAC integration process (World Bank, 2012).

1.1 East African Business Council (EABC) and East African Community (EAC)

East Africa business council acting as Umbrella body of inter trade in the East African member states has the mandate to Promote and act as the gateway to interests of EAC, Business Community and any other links to other interested states in Africa and other parts of the world. By doing this, is actively influencing policy reforms to create a conducive business environment in EAC, participates in key decision making meetings of the EAC and other activities geared towards widening and deepening the EA Integration process. Being a legal body in EAC, it has a well-defined treaty in Article 71a, b, c; Article 74, 75, and 76 in EAC legislature.

For economic growth in developing and developed countries, science, technology and innovation (STI) remains the key entry in attaining any National economy and growth of the GDP. This note has made the EABC to integrate a working paradigm to boost STI in SMEs, corporation to meet the business competition in member states and others of the world. This move has enabled World SME Forum works with the EABC to extend the scope of its activities and programs to the African continent and partnering with leading chambers and SME associations in the region in a bit to improve economic perspectives for SMEs in the region through scaling up of production. The Kenya Association of Manufacturers (KAM) and (GIZ) launched a project seeking to promote manufacturing SMEs in East Africa in 2017.

The project aims to assist manufacturing SMEs expand by providing them with business and technical know-how and capacity development. To improve on its work EABC has achieved the

Adoption of EABC Tax Proposals by EAC Partner States on Sugar, Iron and Steel etc. Removal of Railway Development Levy; Passing of the EAC Vehicle Load Control Act; Removal of several road blocks and weigh bridges along the Central and Northern Corridors; Passing of the NTB bill. Rolling out of the Single Customs Territory. Rolling out of the Regional Electronic Cargo Trucking System by Kenya, Rwanda and Uganda. Tanzania's lowering down of the Work Permit Fees for East Africans to USD 500. Creation of a One Network Area for Uganda, Kenya, Rwanda and South Sudan and over 156 East African Standards harmonized.

1.2 EABC, Science Technology and Innovation (STI)

EABC in its endeavour to promote STI has promoted several SMEs production industries in the member states as shown in the following photographs. The use of energy saving technologies will be essential in preserving the environment and improve public health outcomes (Fig. 1 and Fig. 2).

Figure 1 Energy saving Cooking Jiko
Source: Author: 2017

Figure 2: Small Wind Turbine
Source: Ministry of Energy- Uganda: 2017

mPesa is a Swahili word for mobile money, a cell-phone-based money transfer service developed by Safaricom (Fig. 3). It was registered in Kenya on April 5, 2007. It facilitates financial transactions where the service allows users to deposit money into an account stored on their cell phones, to send balances using SMS technology to other users and to redeem deposits for regular use. mPesa is one of the cheapest financial service systems for low-income earners. It has been estimated that the product had over 17 million users in Kenya as of 2012. The mpesa is used to Send money, withdraw cash, buy airtime, get loans and savings, etc. and this has made other businesses e.g. fruits, clothing, and other SMEs to grow. With high improvement of SMEs through STI, EABC took a study to establish the fastest growing economy in Africa by comparing their GDP and how they get engaged in innovation, science, industries and academia.

Figure 3: MPESA

1.3 EABC Perspective in GDP in Africa

Innovation has an important role in economic growth in the modern world. Most countries with better levels of innovation and technological development have better economic growth, on the contrary, countries with low levels of innovation have worse economic growth, (Contador Harrison, 2015).

Innovation has been screened to be a common term to achieve real change across the entire economy in Africa and beyond therefore, more collaborative effort is called from different stakeholders to sustain this paradigm. It will require industry, government and academia collaboration to strengthen innovation systems and challenge the status quo in any fast growing economy. Academia industry and government need to come up with policies to favour the prism of innovation and entrepreneurialism, this will drive the creation of new jobs and allow Africa to remain internationally competitive in the wake of global village. Industrialized countries found the importance of collaborating the universities, industries and the government for economic development. Fei- yu Chen et.al (2014) found that the triple helix of academia industry-government relations being accepted as an important determinant of innovation and being a new fashion form in East china. Bergman, (2014) found that Gauteng- region city in South Africa in what he called triple helix framework developed after the collaboration of government, industry and academia working towards a common vision of regional development.

1.3.1 Innovation System

A national system of innovation has been defined as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies, (Freeman, 1987). The concepts of national innovation systems (NIS) and innovation in general are increasingly being used by African policy-makers. Some countries reviewing their traditional S&T policies and introducing innovation oriented policies. There is also growing interest in the application of the concept of NIS. Some organization, among many United Nations Conference on Trade and Development (UNCTAD), the United Nations Educational, Scientific and Cultural Organization (UNESCO), the World Bank, and the Organization of Economic Cooperation and Development (OECD) support African Countries to implement the concept of NIS.

However different countries are applying efforts to formulate innovation policies using different approaches. In general a conceptual clarity and absence of a common frame work is still remaining a challenge to many developing countries. The role of innovation system to both developed and developing countries is creation of knowledge to solve the identified bottlenecks recognition of the potential of innovation, creation of incentives to be engaged in IP and creation of markets for it, (Edquist and Hommen, 2008; Johnson, 2008)

1.3.2 Gross Domestic Product (GDP)

OECD defines Gross Domestic Product (GDP) as "an aggregate measure of production equal to the sum of the gross values added of all resident and institutional units engaged in production (plus any taxes, and minus any subsidies, on products not included in the value of their outputs) "OECD". Or is the value of a country's overall output of goods and services (typically during one fiscal year) at market prices, excluding net income from abroad, (Retrieved 14 August 2014). Gross Domestic Product (GDP) can be estimated in three ways which, in theory, should yield identical figures. They are; Expenditure basis: how much money was spent; Output basis: how many goods and services were sold, and; Income basis: how much income (profit) was earned.

From African Economic Outlook (2016), Africa's economic performance has improved. Growth in real GDP is estimated at 3.6%, higher than the 3.1% for the global economy and 1.5% for the euro area. Africa remained the world's second fastest growing economy after East Asia. In 2015, sub-Saharan Africa (excluding South Africa) grew faster than the continental average, at 4.2%, with East Africa leading the way at 6.3%. Growth in Central, North and West Africa was above 3%, while Southern Africa grew by an average of 2.2%. Looking ahead, average growth in Africa is expected to remain moderate at 3.7% in 2016 but could accelerate to 4.5% in 2017. This forecast hinges on the strength of the world economy and a gradual recovery in commodity prices. The African's fastest growing economies are racked as Ivory Coast, Tanzania, Senegal, Djibouti, Rwanda, Kenya, Mozambique, Central Africa Republic, Sierra Leone and Uganda with the GDP growth ranging from 8.5% to 5.3%

1.3.3 Government

Edquist, Ho mmen, (2008: 10), stated that the Government roles in national innovation System is to cultivate an economic and business climate that rewards innovation—such as lower income-tax rates, support basic and early-stage research that stimulates the creation of new fields and

new knowledge, promoting free markets and free-trade agreements which encourage more innovation and the faster adoption of the best ideas, providing tax incentives for the longer-term, bigger bets required for new technologies, protecting intellectual property rights with strong patent, trademark and copyright systems, support innovation best by funding basic research and setting.

Cunningham et al. (2003) commented that, creative industries have the role to fuel the creative capital and creative workers which are increasingly being recognized as key drivers within national innovation systems, marketing and diffusing science and technology, based innovations, goals and activities and aesthetic qualities for products to differentiate them from competitors and make them attractive to consumer., make creative content for innovative ICT applications, producer of innovations in itself acting as knowledge creator, producing new concepts, methods and material outputs, Role of academia (TVET), Universities, Polytechnics, research Institutes in innovation systems is to act as clusters of knowledge based industries "Antenna" for adopting external knowledge and mediator for local knowledge circulation, Source of highly qualified labor, Knowledge provider in university-industry linkages, Incubator for academic spin-off companies, (Smith, 2002).

1.4 Statement of the Problem

Africa's current economic growth rate is far too low. Industrial development has been stalled since the 1970s. The lives of most Africans are marred by poverty, hunger, poor education, ill health, and violence. Every year more Africans live in urban slums and Corruption pasted leadership. However Africa needs to take initiatives to address those problems. In regard to this it is necessary to assess the prospects for a specific new local and international research project through academia and collaboration with government, industries and innovation systems to empower everyone in every state and create an avenue to address the challenges, **(***Foresight Africa: Top Priorities for the Continent 2016)***.** The study focuses on effect of strengthening national innovation system through effective collaboration with; industries, education/ research institution, government and growth in GDP in Africa

1.5 Objectives

(i) Establish the fastest growing economies in Africa by 2016

(ii) Establish the relationship between triple helix (academia industry and government) and the GDP growth of the fastest developing countries.

(iii) Determine the relationship between National innovation system triple helix (academia industry and government) and the GDP growth of the fastest developing countries.

2.0 Literature Review

2.1 Theoretical Foundation

2.1.1 Innovation Theory

Innovation theory, also called diffusion of innovation theory, explains how advancements gain traction and over time spread, or diffuse, throughout a specific population. (Spier 1929).

2.1.2 Institutional Theory

Institutional theory is a theory on the deeper and more resilient aspects of social structure. It considers the processes by which structures, including schemes, rules, norms, and routines, become established as authoritative guidelines for social behaviour. (Richard 2004).

2.2 Empirical Studies

There are a great deal of variations in the potential of various countries engaging in science and development, (Michael, 2000). According to Michel, industrialized countries produce an average of 55.8% of the world GNP and they deploy about 84% of the world growth expenditure on research and development. On the other hand the developing countries produce an average of 2.2% of GNP deploying only about 0.5% of the world growth expenditure on research and development.

Nicholas (2011) notes that the economic success of the Japanese system in the first was supported by the development of the domestic capability rather than by ant inflow of foreign knowledge but now the universities in Japan are moving from national to global collaboration (Lee at el, 2010). Son and Negish, (2010), also points out the weakening collaboration between triple Helix in Japan in favour of the increasing foreign entered nature of the knowledge creation.

2.3 Conceptual Framework

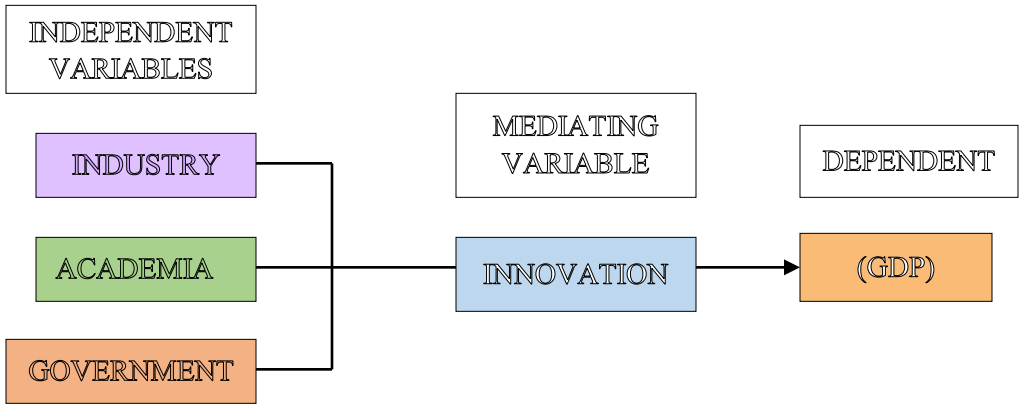


Figure 4

3.0 Methodology

The study used Positivism research philosophy, the researcher was concerned with gaining knowledge in a world which was objective using scientific methods of enquiry. It included surveys through quantitative secondary data which was the norm (Galliers, 1991). The study applied descriptive research design. This design described the characteristics of a population or phenomenon that was being studied. It addressed the "what" question *(*Rangarjan, 2013).

The population compost of the 10 fastest growing economies in African named in 2016. These were Ivory Coast, Tanzania, Senegal, Djibouti, Rwanda, Kenya, Mozambique, Central Africa Republic, Sierra Leone and Uganda with the GDP growth ranging from 5.3% to 8.5% 1.1.3 Gross Domestic Product (GDP) (African Economic Outlook 2016). Secondary data was used. The source was from the previous studies carried out by other organization. The growth in GDP from the countries selected was recorded, the expenditure on innovation, the government funding in R&D, industrial and research in academia from the selected countries was recorded for analysis.

Simple random sampling design was used. It involved assigning numbers to the ten selected countries putting in a box and selecting 4 of them. Mugenda and Mugenda (2003) accepted a sample of 10% from the sample framework. Data was analyzed by calculating the percentages and represented using graphs, tables and pie charts.

4.0 Findings

This chapter gives the finding of the objectives

4.1 Relationship between Academia, Industries and Government and Growth of the GDP of the Fastest Growing Economies in Africa

RANK	COUNTRY	GDP GROWTH%
1	IVORY COAST	8.6
2	TANZANIA	6.9
3	SENEGAL	6.6
4	DJIBOUT	6.5
5	RWANDA	6.3
6	KENYA	6.0
7	MOZAMBIQUE	6.0
8	CENTRAL AFRICA REPUBLIC	5.7
9	SIERA LEONE	5.3
10	UGANDA	5.3

Table 1 Africa's Fastest Growing Economies % in Africa
Source: IMF World Economic Outlook (April 2016)

From Table 1 and Figure 5 Ivory Coast (8.6%) is ranked position 1 as the fastest growing country in GDP by 2016 followed by Tanzania (6.9%), Senegal (6.6%) Djibouti (6.5%), Rwanda (6.3%), Kenya (6.0%). Mozambique (6.0%), Central Africa republic, (5.7%), Sierra Leone (5.3%), and Uganda (5.3%).

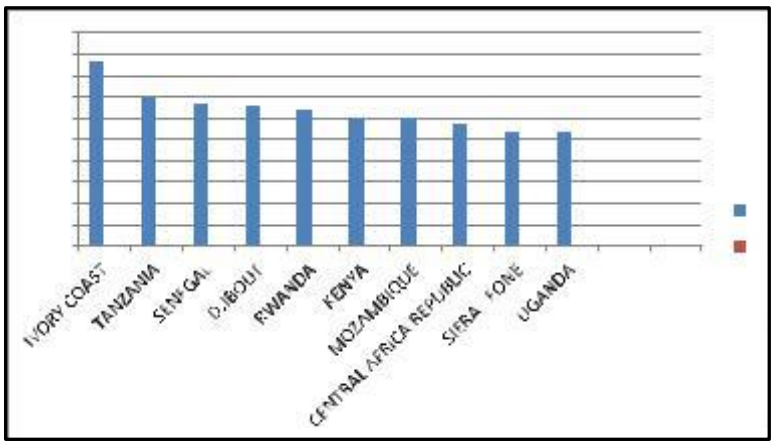
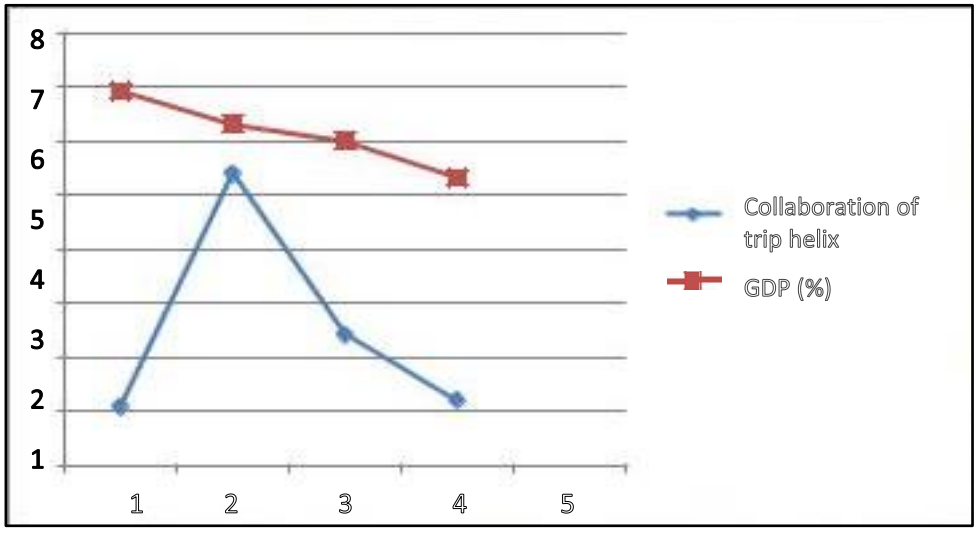


Figure 5 Africa's Fastest Growing Economies in %
Source: IMF World Economic Outlook (April 2016)

4.2 Relationship between Academia, Industries and Government and Growth of the GDP of the Fastest Growing Economies in Africa

Countries	Academia Expenditure R&D (%)	Industries Expenditure R&D (%)	Government Expenditure R&D (%)	Collaboration of trip helix	GDP (%)
Tanzania	1	0.009	0.07	1.079	6.9
Rwanda	5	0.002	0.4	5.402	6.3
Kenya	2	0.011	0.4	2.411	6
Uganda	1	0.19			5.3

Table 2 Relationship between Collaboration and GDP Growth of the Fastest Growing Economies in Africa 2016



Key
1. *Tanzania*
2. *Rwanda*
3. *Kenya*
4. *Uganda*

Figure 6 Relationship between Collaboration of Academia, Industries, Government, and Innovation on GDP Growth of The Fastest Growing Economies in Africa 2016

From both table 2 and figure 6, there was no defined relationship between the triple helix collaboration (1%) and GDP (6.9%) growth in Tanzania. Rwanda had a high level of relationship between triple helix collaboration (5.492%) and GDP (6.3%) growth than other Countries. Kenya collaboration scored (2.411%) and GDP (6.0%). Uganda scored in collaboration (1.193) with GDB (5.3). Kenya and Uganda had significant positive relationship but with little score in collaboration compared to GDP growth.

4.3 Relationship between National Innovation System and GDP the Fastest Developing Countries in Africa 2016

Countries	Academia Expenditure R&D (%)	Industries Expenditure R&D (%)	Government Expenditure R&D (%)	Collaboration of trip helix	Innovation (%)	National Innovation System	GDP (%)
Tanzania	1	0.009	0.07	1.079	1.38	2.459	6.9
Rwanda	5	0.002	0.4	5.402	57,54	62.942	6.3
Kenya	2	0.011	0.4	2.411	16.55	18.961	6
Uganda	1	0.005	0.19	1.195	24.8	25.995	5.3

Table 3 Relationship between National Innovation System and GDP of the fastest developing countries in Africa 2016

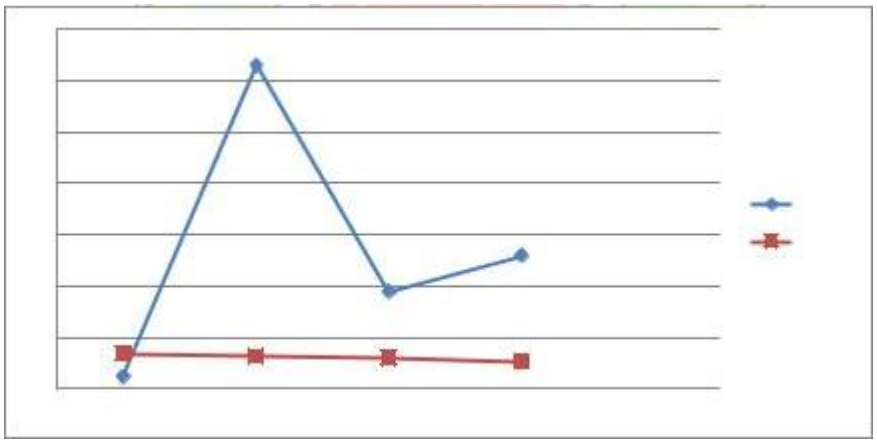


Figure 7 National Innovation System and GDP of the fastest developing countries in Africa 2016
Source: Author: 2017

5.0 Discussion and Conclusion

Countries with the Fastest Growing Economies in 2016

The following countries were found to do well in their economy in 2016: Ivory Coast, Tanzania, Senegal, Djibouti, Rwanda, Kenya, Mozambique, Central Africa Republic, Sierra Leone and Uganda.

A survey done by (African Economic Outlook 2016), showed Africa had grown in real GDP estimated at 3.6%, higher than the 3.1% for the global economy. The paper further found that

East Africa had the lead with 6.3 growth from other regions of Africa. This reflected the finding of this paper since out of the 4 sampled countries three of the; Kenya, Uganda, Tanzania and Rwanda are in the East African region.

The Relationship between Triple Helix (Academia Industry and Government) and the GDP Growth of the Fastest Growing Economies

From the study Tanzania had no relationship between the triple helix and GDP growth. Kenya, Uganda and Rwanda had a defined relationship. Rwanda showed high scores than both Kenya and Uganda. So this shows that improved GDP leads to good collaboration between academia research and government. Study by World Bank group competitiveness (2015), found Kenya to spend little funds in the research and development. The finding tallied with the research paper where Kenya ranked position 3 in the four courtiers that were sampled for the study. Study by Harrison (2015), found Kenya to have little collaborating with the academia, government and industries. However the research paper findings showed Kenya ranked position 2, re-electing moderate shift from the previous findings

The Relationship between National Innovation System Triple Helix (Academia Industry and Government) and the GDP Growth of the Fastest Developing Countries

From the study NIS has relationship to GDP in Rwanda, Uganda and Kenya, Tanzania has no defined relationship to the NIS system

Acronyms and Abbreviations

EABC	East Africa Business Council
EAC	East Africa Community
NIS	National Innovation System
R&D	Research and Development
TVET	Technical and Vocational Education Training
GDP	Gross Domestic Product
UNCTAD	United Nations Conference on Trade and Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
OECD	Organization of Economic Cooperation and Development

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Linking Between Industry and Science and Technology: Experiences of Inclusive/Community-Based Innovation

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Abstract

The capacity of a country or continent to develop mechanized methods of processing its natural resources determines to a great extent its level of development. Fundamentally, the bedrock of advanced countries is structurally fortified by advances in science, technology and innovation. These result in economic, sustainable and inclusive development. The slow pace of industrial development in Africa is directly proportional to its laissez faire attitude to adoption of modern scientific and technological developments, thereby leading to increasing rate of unemployment, inability of communities to process their natural resources, loss of value chain benefits through export of raw materials, and dearth of manufacturing industries.

Towards achieving rapid economic and industrial development, an inclusive/community based innovative approach is being demonstrated in the government owned institute; Advanced Manufacturing Technology Programme (AMT-P), Jalingo, Taraba State, Nigeria. Many indigenous processing methods have been mechanized through regular interactions with the community members and AMT-P researchers. Notably, the livelihood of the farmers has been improved in the areas of rice processing, grain threshing, animal feed production, fish and vegetable drying. Significant government intervention through Public-Private Partnership model is recommended for fast-tracked inclusive growth and industrialization.

Keywords: *Innovation, Community, Inclusiveness, Science, Technology, Industry.*

1. Introduction

Africa is endowed with abundance of natural and mineral resources. Of the total world mineral resources, 90% of the global diamond market supply comes from Africa, 81% of cobalt, 62% of platinum, 70% of gold, 50% of magnesium and chromium, 30% of copper of global market

supply also comes Africa. Africa also produces 66% of world cocoa, 66% of sisal, 95% of groundnut and 25% of coffee beans and cotton (Okorafor, 2014). The reality, however, is without Industrial and Science and Technology synergy, these resources will be of waste and there will be no meaningful development across the Continent of Africa.

Development at any phase is always linked with technology and technology is driven by advancement in science. Hence, Science, Technology and development are all proportional to each other. Developed economy of the world is driven by science, technology and engineering and industrial revolution. For any meaningful Socio-economic growth across the continent of Africa, there must be synergy between industry and science and technology.

It is important to define precisely what Science and Technology is and to further link it up with the industry, which focuses on community-based innovation. Science is a constellation of systematic activities for the understanding and discoveries of universal truths and principles. Technology on the other hand, is refer simply to as the process making tools, machines, contrivances and materials in the course of production (Han, 2007). Science, Technology and Innovation (ST&I) have been for creating knowledge-based economies, they may also contribute to social and ecological dimensions of development. Evidence suggests that those countries that are able to steer ST&I processes towards knowledge-based economies enjoy more economic growth and prosperity than those who do not (Hornidge 2011; Bechmann *et al*. 2009).

There are different scientific models and conceptions of how ST&I contribute to different aspects of development. Reviews show that scientific models and conceptions are divided into three ideal-type categories: ST&I for economic development, ST&I for sustainable development and ST&I for inclusive development.

As science-based industries develops they remain dependent on the continuous inputs from the results (Science) obtained from the researchers from most our research-based institutes and universities. These industries depend on the technological development of these ideas in order to grow and widen their range of products.

2. Relevance of Technology to Industry

It is unbeatable that technology makes production processes more efficient, thereby increasing the competitiveness of countries and reducing their vulnerability to market fluctuations. Technology can be referred to the art and science of applying knowledge to meet man's needs (Okorafor *et al,* 2014).

Africa remains a weak link in the global world economy because of it low level of technological attainment. According to Yong (2017), stated categorically that "Africa is by no means destined to lag behind the rest of the world economy. But to fulfill its economic potential, Africa must be industrialized".

Technologies are rarely perfect when they come "off-the-shell" (Mashi, Inkani, Yaro, 2014). The level of technology is an important determinant of economic growth. The rapid rate of growth can be achieved through high level of technology. Schumpeter observed that innovation or technological progress is the only determinant of economic progress, but if the level of technology becomes constant the process of growth stops. Thus, it is the technological progress which keeps the economy moving. Inventions and innovation have been largely responsible for rapid economic growth in developed countries.

3. Inclusive and Community-based Innovation

Technology and innovation are crucial for addressing the challenges of low structural transformation and inclusive development in Africa.

Innovation, traditionally defined as the development of new goods, services, or processes, has long been an important driver of positive outcomes such as economic growth and societal well-being. In other words, Innovation can be described as the means by which individuals and groups apply their creative, adaptive capacities and their social, organizational, and institutional knowledge for the generation and application of new scientific and technical knowledge (ICSU-ISTS-TWAS, 2005).

Innovation is the development and implementation of ideas for new or improved products, services, production technologies or organizational arrangements. It is the fundamental driver of long-run economic growth.

However, a range of longer-term trends combined with the recent financial crisis and slow recovery have made it obvious that innovation also plays an important role in creating negative outcomes, such as income inequalities (Schillo and Robinson, 2017).

Gerguri and Ramadani (2010), highlighted some important definitions of innovation from the aspect of customers, innovation means products with better quality and better services, which together mean a better way of life. From the aspect of businesses, innovation means sustainable growth and development, realization of great profit. For the employees, innovation means new and more interesting job, which requires more mental faculty, which results in higher salaries. From the aspect of whole economy, innovation represents a bigger productivity and prosperity for all. To make innovation happen, practical ways must be explore to address specific innovation challenges; harness the true value of innovation and create an environment where new ideas, products, services and ways of working are encouraged and supported.

Innovation can also be classified based on the degree of newness and impact. This newness is classified on a scale between the two extremes; namely: incremental and radical innovation. Incremental innovation refers to the improvement of an existing design. The design of a single component changes, but the core design and links between components remain the same. Radical innovation establishes a new/novel design that significantly differs from past practice in terms of the core designs and the architectural links between Components (Botha, 2017).

3.1. Inclusive Innovation

Inclusive innovation is an innovation system in which opportunities to participate in innovation are broadly available to all and the dividends of innovation are broadly shared by all. Harness the true value of innovation and create an environment where new ideas, products, services and ways of working are encouraged and supported.

Cozzens and Sutz (2012) directly address inclusive innovation: "innovation needs to be 'inclusive' in at least two ways: inclusive in terms of the process by which it is achieved and inclusive in terms of the problems and the solutions it is related to". For instance, South Korea's transformation from an agrarian economy to an industrial knowledge-based economy was achieved through policies of constant learning which is Science and Technology and Innovation. During the 1950s and 60s, South Korea was exporting low- cost labour-intensive manufactures such as plywood, wigs, toys and textiles. During the 70s, as skilled South Korean workers mastered foreign technologies and gained experience, they began exporting ships, steel, consumer electronics and construction services. By the mid-80s S. Korea moved towards the next phase of industrialization characterized by skilled, labour-intensive industries, computers, semi-conductors, memory chips, video cassette recorders, electronic switching systems, automobiles, industrial plants and other technology and knowledge intensive products.

In the 90s, the S. Korean workers began working on the next generation products such as multi-media electronics, high definition TVs, personal telecommunication systems. An important factor contributing to the economic growth of S. Korea as cited by Young (1993) and Krugman (1994) was the rapid expansion of employment in manufacturing, mainly due to the adoption of an outward, export-oriented development strategy that allowed for rapid increase of labour demand and incorporation of new entrants into economy.

An export-led economic growth model and appropriate system of incentives provided the direction for industrialisation. Export-oriented growth strategies helped S. Korea achieve industrial specialization, which involved constant innovation in the improvement of products and processes and generated a sustained demand for highly skilled human resources. Indeed export-driven strategies are argued to be among the most important factors explaining the success stories of S. Korea.

3.2. Industrial Growth in Africa

Africa is highly diverse in its economic, social and political structures, but the continent's countries share common characteristics and face similar challenges, such as low levels of socio-economic development, high vulnerability to risks, lack of power, and insecurity. It is a known fact that no investor can invest in environment where there are unrest and threat to lives and property.

Africa also remains on the margins of industrialization, as reflected by low and declining shares of Manufacturing Value Added (MVA) in Gross Domestic Products (GDP) since 1970. Africa's MVA accounted for only 1.6% of the global total in 2014 and its growth has lagged behind that

of all other regions since 1990 (UNIDO, 2016). Moreover, there is only shallow participation of African economies in global value chains, with Africa adding value to only 14% of its exports, compared with 27% for emerging Asian economies and 31% for developed economies (Yong, 2017).

Industry contributes significantly to the accumulation of physical and human capital. It provides relatively well-paid jobs for large numbers of unskilled or under-educated workers especially those who are not integrated in the formal economy, which increases household income and, hence, domestic demand. Going by this, industry generates substantial backward and forward linkages with other sectors, providing a wealth of opportunities for suppliers, distributors, retailers, and business services (Landry, 2018).

Local manufacturing needs to be encouraged by providing enabling environment for them through enactment of carefully tailored deliberate policies that will provide rapid and sustainable socio-economic advancement. Generated ideas including those accruing from basic research t should be transferred to industries for transformation into useful tangible products that will deeply impact positively on the society.

4. Methodology

4.1. Harnessing African Indigenous Technologies for a Diversified Economy

The bane of Africa's underdevelopment may be pinned to its inability to process the abundant natural resources/raw materials into useful products for both domestic and international consumption. It is clear that no matter how endowed a country is, it could not claim development through the exportation of its raw natural resources. Historically, African indigenous technologies were used by its people to process various materials into useful products. However, such technologies were mostly crude, manual, ineffective and inefficient. Notwithstanding, such technologies have direct relationship with the culture of the people and thus the end-products are seriously considered significant in defining the innovativeness of the people and to some extent their economic viability. The infiltration of foreign technologies into Africa facilitated the death of the traditional technologies without necessarily providing the required solutions for the people.

In view of the above, it is mandatory for Africa to resuscitate her abandoned indigenous technologies and protect the existing ones in order to allow economic diversification at the grass-root. To achieve more efficient and sustainable economic diversification, the hitherto manually operated technologies may be upgraded to encompass a reasonable level mechanization that will improve productivity without necessarily altering the traditional flavour of the end-product.

Africa is greatly blessed with gifted hands that are laboriously engaged in various types of indigenous technologies. For instance, there is hardly any part of Nigeria that does not have a remarkable indigenous technology to show for its existence. (Willie *et al*, 2012) stated that indigenous industries among others include the production of pots from clay and aluminum metal scraps, textile making, cloth weaving, bronze casting, leather tanning, various agricultural tools and machines in various parts of the country.

According to African Review of Business and Technology in its 2018 publication, Africa's manufacturing output could double within a decade reaching the US$1trn mark by 2025. Three-quarters of output expansion could derive from meeting growing domestic consumer and business demand, reducing the volume of goods that is imported. Others could derive from boosting exports. Kenya, Ethiopia, Tanzania, Rwanda. Ghana, Senegal and Mauritius are expected to undergo some degree of industrialization, along with Nigeria.

5. Results and Discussions

5.1. Inclusive/Community-based Innovated Outputs in Advanced Manufacturing Technology Programme (AMT-P), Jalingo

Taraba State (Fig. 1), located in the North-eastern part of Nigeria has a total land mass of about 6million hectares out of which about 4 million hectares are arable and about 1.3 million hectares are put under crop cultivation annually (Umar *et al*, 2014). Taraba is well endowed with abundant surface water which includes ponds and rivers and has about 500,000 hectares of water body and 142 natural ponds (Orunoye, 2014).

Major crops: Maize, Millet, Sorghum, Rice, Yam, Cassava, Sweet potatoes and Groundnut.
The average fish production**:** About 1,987 metric tonnes per annum (TSEED, 2004).
Daily fish catch in some LGAs like Ibi, Lau and Donga is about 3000kg. The state has more than 30,000 fishing families fully engaged in daily fishing.

Taraba State, where AMT-P Jalingo is located, is basically an agrarian state like many parts of the country where abundant natural resources abound and majority of the populace are engaged in labour-intensive subsistence farming. However, their inefficient farming techniques are trailed by significant quantity of wastes that are recorded annually due to activities ranging from poor land preparation to the point of harvest and storage. To improve on this, intervention in form of innovations based on science and technology must be introduced.

Fig.1: Map of Taraba State in Nigeria, West Africa.

AMT-P established in 2010 through the implementation of the National policy on Science and Technology, which has its mandate as sourcing, acquisition, development and application of Advanced Manufacturing Technology for the production of component, machinery and their production systems and transfer of the same to satellite industries. The centre over the years has embarked on meaningful innovative projects through its Research and Development (R&D) department. Figures 2-12 are some of the innovative projects embarked upon for onward transfer to satellite industries. Some of these products are patented (figs. 2 – 5), figures 6 – 10 are developed and transmitted to local industries while figures 11 and 12 are awaiting development amongst others.

6. Conclusions

Africa is endowed with massive natural resources but mostly relies on foreign technologies for exploitation and processing. Majority of Africans do not have access to such technologies and thus continue to use the indigenous technologies that are less efficient. To achieve any reasonable development, it is necessary to upgrade the indigenous technologies in order to achieve both effectiveness and efficiency. After careful interaction with the communities to determine the suitably selected technologies, upgrading of such through mechanization requires government intervention in terms of both policies and funding. One of the recommended strategies is to adopt public – private partnership (PPP) arrangement, where outputs of upgraded indigenous technologies are rapidly absorbed by the private entrepreneurs who serve as the satellite industries to popularize it for the benefits of the communities. In view of that, a synergy between industries and science and technology that will guarantee fast-tracked economic growth across Africa has been established.

Fig. 2: Rice Thresher

Fig.3: Magami Multi-grain Thresher

Fig. 4: 20.0 JE Fish dryer

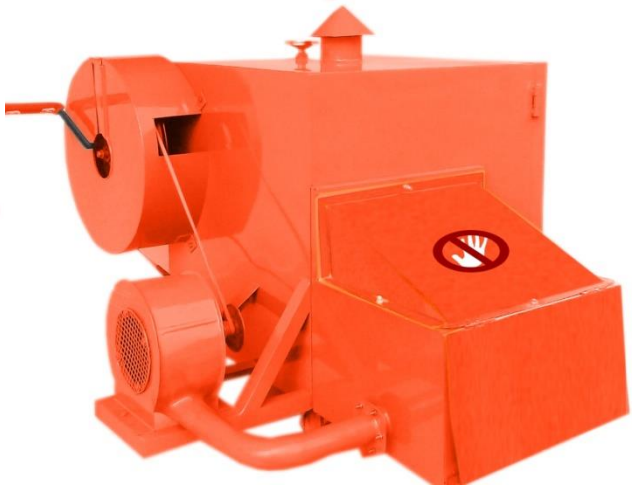

Fig. 5: Fish dryer

Fig. 6: Combined Fish Feed Mill

Fig. 7: 2018 AMT-P Thresher

Fig. 8: Dual Purpose Harvester

Fig. 9: AMT-P Semi Automated Loom

Fig. 10: Interlocking Brick Machine

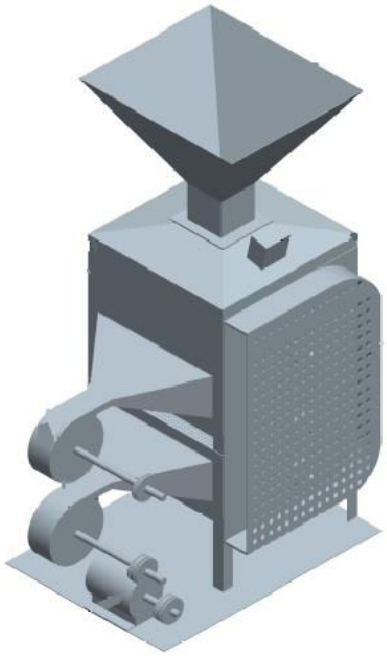

Fig. 11: Rice Dryer

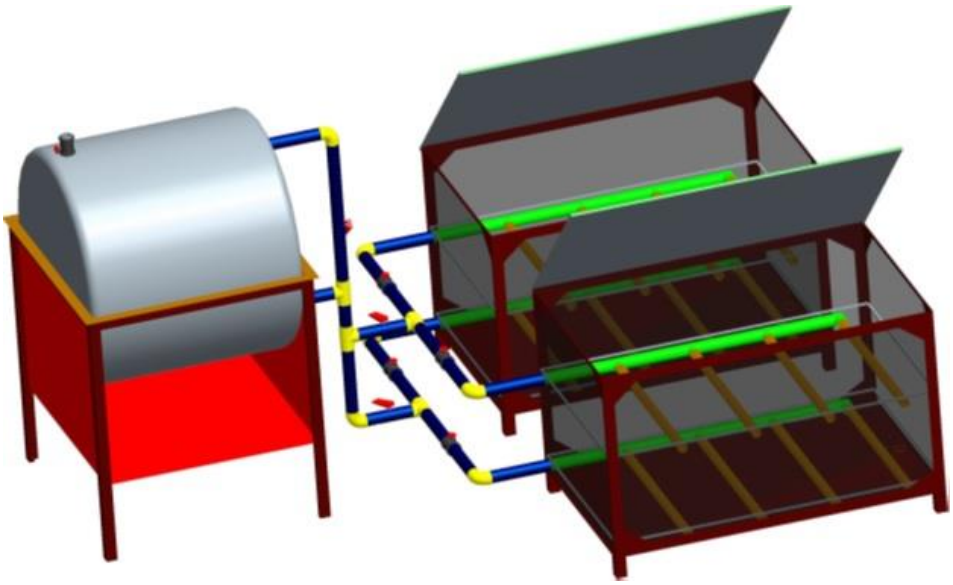

Fig. 12: Rice Boiler

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Research Partnerships and Eco-Innovation Approaches towards a Sustainable Economy – Bridging the Gaps between Academia and Industry in Africa

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Abstract

As Africa witnesses an increase in private sector investment, technological development and industrialization across a wide range of sectors, there is need for national policy level considerations of sustainable industrialization models that ensures green economic growth**.** The role of universities and research organizations in this framework is crucial but the disconnect between research and the research user community in Africa, poses a big challenge. One of the biggest agenda in universities globally is internationalization which can be enhanced through ensuring strategic partnerships that supports multi, inter and trans-disciplinary approaches to research. In addition, ensuring strategic partnerships that research organizations have with the users of research, in this case industry, is also significant to meeting sustainable development. Eco-innovation as an agenda, has the capacity to deliver the mechanisms needed for green growth and sustainable development. Those mechanisms will be essential to producing commercially successful products, services and technologies that reduce the impacts of human activities on the environment, achieve more efficient/responsible uses of natural resources and enhance societal, economic, and technological resilience to environmental pressures. However, it must be clear that eco-innovation cannot be achieved without qualitative research, resource mobilization and appropriation which must be driven by government policies with a focus on sustainable solution-oriented research models that bridges gaps between academia and industry.

Keywords – *Eco-Innovation, Knowledge-Transfer, Research-Users, Sustainability, Internationalization*

1. Introduction

In an era where global concerns about environmental issues are at a peak as shown by the current drive of high level international and national government authorities, business corporations and the international community towards environmental sustainability, African organizations and especially universities have a role to play.

According to *The Africa Competitiveness Report 2017 put together by the World Economic Forum, The World Bank and The African Development Bank there is a* growing international attention focused on Africa as an investment destination and mounting talk of an African economic renaissance. The report emphasized the enthusiasm in global players driven by ten years of increased strong growth in Africa amidst the global economic crises that other continents of the world have faced.

With over a billion people and averaging growth rates of over 5 percent in the last decade, the continent needs to wake up to establishing and aligning itself with globally emerging environmental themes and African universities should be leading these discussions. In December, 2015, the Paris Climate Agreement which is an agreement of the United Nations Framework Convention on ***Climate Change*** (UNFCCC) was negotiated and adopted and in the same vein, the United Nations through a deliberative process with 193 Member States launched 17 ***Sustainable Development Goals (SDGs)*** with 169 targets between them as a 2030 agenda for transforming our world. These two form huge emerging themes in line with global environmental sustainability and offers an opportunity for Universities to take the lead and transform the sustainability agenda in Africa through its national policy alignment, stakeholder engagement, determination and fulfilment of its Intended Nationally Determined Contributions (INDCs), strategic capacity building, comprehensive education and national awareness and implementation strategies to enable effective execution and compliance. For African universities to align with these global agenda and to lead the discussions, they would have to understand, develop and implement new internationalization and innovation policies and strategies.

Internationalization of and innovations in Universities and research organizations are the biggest term in use in the international education circles. In a global village like the world is today, internationalization of and innovations in education and research is a crucial engine that drives international competitiveness and ultimately economic and social revolutions. Developing an internationalization and innovation agenda for a University and research organizations and its authorities has the following benefits:

1. Developing its brand, profile and relevance both nationally and internationally.
2. Increase its interaction and engagement with the private sector and governance for sustainable and impactful applied-focused research.
3. Delivering social, economic, academic and spiritual impacts of international standards on its students for consequent impacts on national economies.

4. Developing a graduate portfolio that is employable in any part of the world due to uniformity in competence and acquired skills.
5. Increasing extensive independent revenue generation streams for the University and the successful sourcing, application and winning of international research grants and funding.

Funding and in some respects, resource mobilization is one of the biggest challenge facing African universities. It is a major impediment to internationalization and innovations through research. Yearly, managers, directors and administrators of African Universities and research organizations strive to develop their skills and capacity to be able to bridge the competence gaps in their organizations and universities and this is one of the fundamental roles of Vice Chancellors and University managements. However, in an era where there is an increase in the numbers and sources of international grants focused on Africa, African institutions still struggle to align themselves with these funding opportunities and even lack the capacity and institutional skills to source, apply for and win these sorts of grants.

In most African countries, public universities depend wholly on federal government who now struggle to fund them; they don't engage strategically well with private sector organizations or industry who can potentially fund them; personal consulting is huge but secretive and not well structured to bring revenue to the universities and so institutions benefit nothing; they don't recruit overseas students who can give more in tuition fees through international engagements; Memorandum of Understandings (MoUs) that can attract funding are not well operationalized after gather dusts on shelves; access to increasing international research grants is a struggle; and when they apply for grants, proposals are poor; delivering short professional courses for revenue is an alien concept; investing in distance learning and exploiting the huge potential for distance learning is still unclear and problematic. The situation is not so much different in private universities either and the ultimate problem is their minimal engagement with industry.

As such, another big challenge with African universities is the huge gap between academia and research and the private sector/industry and government. By geographical and operational disposition, African universities and research organizations seem cut off from industry and this has affected its relevance, capacity to produce high quality and employable graduates and also the capacity to produce goods and services that solves practical challenges in the society.

With increasing industrialization against a backdrop of increasing populations, waste and pollution and its management is arguably one of the most crucial environmental challenge facing Africa and therefore the need for sustainable waste and pollution management approaches cannot be overemphasized. This has arisen out of the realization that the wastefulness of our industrial society compromises the ability of nature to sustain our needs and the needs of future generations. In a developing economy like Nigeria as it is in several developing economies in Africa, where development of infrastructure, facilities, products and the delivery of services is increasing rapidly, this becomes crucial and a need to understand what to do with generated wastes as a result of these developments, becomes vital.

Emerging themes consider aligning waste and its pollution of the water table, air pollution dynamics and the subsequent negative impact on the health and well-being of communities. The

issues of waste management in Nigeria is somewhat a complex one when you consider the disconnect between research organizations, private organizations and industry who generate these wastes and public agencies whether Federal, State and the local government authorities, whose role it has inherently been to manage waste generated and implement waste management policies. As long the disconnect between research and the user community, industry and government exists, sustainable solutions to Africa's challenges will persist. The question is understanding which of these segments should drive and maintain the conversation and collaboration for sustainability.

Currently, global models show that African universities can be great setups in co-designing and supporting research-driven eco-innovation partnerships with businesses which ultimately deliver "sustainable solutions". Beyond supporting co-designed researches, they can also be fundamental to produce student skills and talents that would maintain a sustainable agenda through innovative thinking and enterprises. However, exploiting the power of universities to drive African eco-innovation will require significant capacity building to bridge the current, very significant gap between academia and industry in Africa.

2. Method and Techniques

This work has been carried over a period of one year engaging with a wide range of stakeholders from universities, industry and government in different African counties. The key objectives of the research study aimed to address four main questions namely:

1. What does universities understand about internationalization within the context of developing strategic partnerships with industry and other research user communities – civil societies, government etc
2. What are the key challenges with working with industry within the context of sustainable development?
3. How is eco-innovation an important model for bridging the gaps between research and the users of research for sustainable development?

The research study has comprised of a combination of desk-based study on four key African countries (Nigeria, Ghana, Kenya and Zambia) and visits (travels) to each of the four countries for field-based qualitative research.

A. Desk-based Study – online, institutions website, newsletters, case studies, regional and country-specific report, articles and information etc
B. Qualitative/Field Research – Telephone interviews, meetings, questionnaires and face-to-face interviews as well as academia-industry forum and workshops.

3. Results and Discussion

Universities personnel had interesting ways of describing internationalization within the context of developing strategic partnerships. A summary of what internationalization meant across a range of universities are:

1. Visibility
2. Exchange Programs

3. Research-Industrial collaborations
4. International outlook and presence.
5. International Research
6. International Conference
7. Societal impact
8. Research publications
9. International Students
10. International Staff
11. International programmes
12. Access to scholarship
13. Ability to attract founding

Of the different expressions of what internationalization stands for, the key concentration was research and strategic partnerships. The agenda of 'publish or perish' was raised on several occasion which describes the situation where African researchers are under intense pressure to publish research papers as this is the central route to getting promoted and climbing the career ladder. However, it was noticed that most of the research they carried out was not driven by a compulsion of interest to provide solutions to practical societal challenges. It was mainly for publication and promotion.

The respondents raised concerns and stated a list of challenging factors that have been limiting to the process of setting up strategic partnerships or the overall success of strategic partnerships with international partners to drive internationalization. These included:

- **Finance and Resources** –This was the most commonly mentioned factor that militated against the smooth process or successful setting up of partnerships. There was the limited availability of finance for travels to visit the overseas universities or to host the overseas universities or partnership events or programmes in their locations. There was also the issues around extra payments to the staff members for extra work on partnerships, or the availability of resources like internet connectivity, support staff, office work spaces to support partnership activities. There was also mentioned the lack of agreement on expenditure and budget allocation to partners during the set up process. So in a sense, in some cases it wasn't so much the availability of funds but the ownership or allocation of the same.
- **Expertise and Understanding** – Some of the respondents made it clear that they lacked sufficient knowledge or expertise on a few issues regarding the partnerships they had:
    - Some partnerships were set up without their knowledge or input.
    - Some partnerships were set up before they took office as Partnership leads without a rounded knowledge of the activities or process of the overseas partner institution.
    - Some partnerships were set up without a well thought out strategy on actionable plans to achieve partnership objectives.
    - Some partnership agreements were expired and needed revisions but the understanding of how to jump-start it was an issue.
- **Interest** – Some of the respondents mentioned the lack of interests from different circles of their universities to pursue partnership objectives especially after the MOU has been signed. It

would seem that the benefits of such partnerships might have not been fully understood or the amount of resources needed to deliver the partnership was misconstrued.

- **Administrative Complexity** – This was pointed as an issue in setting up and driving some partnerships with overseas institutions. The exact responsibility for the driving of a partnership objective was fundamentally a responsibility of the Partnership Lead in all of the Universities questioned. This partnership lead usually sat in the Office of Exchange and Linkages (like in University of Benin Nigeria) and in one of the Universities (like the University of Uyo), it was the Directorate of International Programmes. In some of the cases, this leadership sat under the purview of the Vice Chancellor or the Deputy Vice Chancellor Administration and in some cases the Deputy Vice Chancellor Academics. However, the actual actions to make a partnership work lied in the programme department as was spotted by some respondents. Therefore the administration of such partnerships proved challenging especially when there was an administrative gap between the Department and the office of the Partnership Lead.
- **Documentations** – Some of the respondents mentioned that for some of their partnerships which has taken so long to set up, documentations and in several cases data, has been a challenge. This was mostly the case when the Nigerian University initiated the partnership process with an overseas partner. Documentations requested for which they hadn't put in place included their internationalization strategy documents, their partnership policies, business plans and research profiles.
- **Clarity of Roles and Responsibilities** – Some of the respondents also mentioned the fact that there was some ambiguity in terms of clear roles and responsibilities of partners during the partnership process and the signing of MOUs. The lack of clarity as to who does what, why and when, has posed a huge challenge in achieving partnership objectives.

A follow-up investigation was to find out how researchers viewed working with industry professionals and this was framed in a 'like' vs 'dislike' context of a working relationship. When academics and researchers were asked what they disliked about working with industry, the summary of their responses were captured as follows:

1. Industry are not systematic in their approach to work or solving problems
2. Industry focused more on profit or immediate financial gains as against social responsibility
3. Industry interests in research was only for exploitation for profits.
4. Industry are non-committed to the sponsorship of academic research/development.
5. Industry have wrong perception of academics with respect to their approach to solving problems and training of students for industry.
6. Industry are secretive and not committed to sharing knowledge.

When academics and researchers were asked what they 'liked' about working with industry, the responses were captured as below. They felt:

1. Industry are resourceful and efficient in managing resources.
2. Industry are aggressive and focused on their core mandate. e.g. Profit
3. Industry give adequate supervision leading to high productivity.
4. Industry are committed to stay competitive and relevant.
5. Industry has their remuneration tied to their performance and output.

6. Industry's approach to problem solving is very contemporary and flexible
7. Industry display aggressive advertisement of product and services for value and impact.
8. Industry were fundamental to give students from academia, the required work experiences they needed to be effective and employable upon graduation.

On the flip side, when industry professionals were asked what they 'disliked' about working with academics and researchers, the responses were captured as follows:

1. Academia worked in isolation and do not involve industry in the designing of curriculum
2. Academia are more focused on theory than practical and so research for impact is very limited.
3. Academia's communication of research output is restricted to research paper publications which is not easily accessible and understandable by industry and other communities.
4. Academia are not so efficient in the management of resources or in the sourcing of resources to meet desired goals and research objectives.
5. Academia not demanding feedback from industry on how their products are performing
6. Academia has a strong push for research as a basis for promotion and career progression with little focus on solving practical societal challenges.

The responses highlighted the issues that enforces the disconnect between research and its impact in Africa. However, this also highlights the need for a compromise to be reached if academia is to work with industry for effective impact and resolutions to societal and environmental challenges.

Government, academia and industry, are three segments crucial for cohesive and inclusive national development and sustainable environmental development on all fronts. From a theoretical perspective, government have and focus on 'power' academia have and focus on 'knowledge' and industry have and focus on 'money', and this individual agenda they possess seems to form the basis of their isolations and disconnect.

In Nigeria, there are established Federal Ministries of Environment, State Ministries of Environment, a number of Federal, State and Local Environmental Agencies and parastatals dealing with issues relating to the environment. And in most of the established Nigerian Universities (public and private), there is a department of environment with several academics researching on one environmental issue or the other in addition to the number of students graduating in the environment/sustainability space in Nigerian universities. The only segment in Nigeria that doesn't seem to have as much environmental and sustainability profile integrated into their framework is the private sector/industry and yet they have huge impact on the environment.

The only industry or private sector segment that has had predominant leadership in the environmental sustainability agenda in Nigeria is the extractive industry and this has been predicated by historical, political and economic pressures. Howbeit the same sector has been responsible for most of Nigeria's biggest but most importantly visible and media-profiled environmental crises – the huge degradation of the Niger Delta of Nigeria and the continuous flaring of gas by its operators remain a constant torn on the flesh of sustainable development and

negates the objectives of the SDGs. However, does this mean that these are the biggest environmental sustainability issues that Nigeria faces? Or has the media focus and national economic dependence on the extractive sector provided a good cover and taking away focus on other industry sectors to slip under the radar in their environmental irresponsibility?

In a recent conversation with a senior banking executive in Nigeria, he critically but ignorantly argued that his bank didn't have much environmental footprints in comparison to the oil and gas operators. However, with over three hundred branches all of whom operate constant diesel generators; over 10,000 staff members (more than a third of whom have fossil-fuel cars); over 20,000 ATM machines all of which are powered by some form of fossil fuel; huge paper waste generation; massive water consumption etc., it is clear that the bank does have a massive environmental and carbon footprint. If one was to explore the bank's supply chain and carry out an environmental audit of its national environmental aspects and impacts, it would soon become clear that there has been an overbearing focus on only the extractive sector in Nigeria as the principal avenue for all our environmental sustainability woes. If we began the assessment of the manufacturing, construction, transportation, agriculture and other high environmental-impact industries, then a much grand picture of the role of the private sector in the sustainability discourse in Africa will clearly emerge. This is a conversation that needs to happen in Africa and the need to bridge the gaps between academia and industry have not been greater than it is now.
The impact of national policy and regulations in supporting in specific terms the regulation and management of environmental sustainability in the extractive sector has been responsible on many levels for the current state of appreciation and or awareness of environmental sustainability in that sector. In line with international best environmental practices, Nigeria has put in place several national laws fashioned to regulate greenhouse gas emissions resulting from its extractive industries. Some of them are:

1. Constitution of the Federal Republic of Nigeria 1999 (as amended)
2. National Environmental Standards and Regulations Enforcement Agency Act
3. Oil and Pipelines Act
4. Petroleum Act
5. Associated Gas Re-Injection Act
6. Hydrocarbon Oil Refineries Act
7. Nigeria Extractive Industries Transparency Initiative Act
8. National Oil Spill Detection Response Agency (Establishment) Act
9. Nigeria National Petroleum Corporation (NNPC) Act
10. Oil in Navigable Waters Act

This environmental sustainability inclined laws and regulations though laudable in intent and impressive in declaration have not lived up to their expected output and impact due to the poor implementation regime or framework. It is a known that in some cases, players in the extractive sector prefer to pay the fines and penalties associated with non-compliance which are usually measly and somewhat insignificant in comparison to the profitability associated with non-compliance and the status quo. So, the question is 'would heightened implementable penalties be good deterrents to environmental irresponsibility for the private sector?'. But then another consideration is that even with all these policy frameworks in place in and for the extractive

sector, there are still significant upheavals to meeting a sustainable focus, how much more other industry sectors with little or no environmental guidance on a policy front.

On the flip side, if there is a focus on profitability and bottom line as is usually the most important driver for the private sector, wouldn't a national policy framework that encourages and integrates a profitability agenda make sense?

Another investigation during this study investigated which segment (academia, industry or government) did stakeholders believe should drive the conversation of them collaborating and working together for impact. After assessing over 1,000 stakeholders from the three different countries of this study (Nigeria, Kenya, Ghana and Zambia), the views of who should lead and drive the conversation varied from one stakeholder to another. What was most significant in the investigations was that all the three segments (whether government, academia or industry) has a clear justification why they should lead the conversation of collaboration. It therefore highlights the need for appreciating that any segment which fully understands the benefit of collaboration, should drive the conversation. This seems to be very important especially in developing economies of in systems where there are lots of economic and political instability.

In developed economies, it would seem that the government through policy drives the conversation between all segments for a collective cohesion and national development. In all African countries, universities and by implication research is driven and managed by government. Also, promotion and career progression is related to performance set by governmental rules and regulations.

Therefore, it almost presents a case for a three-fold national policy framework to increase the interaction between research and industry for sustainability and impact. This would be presented as:

- A penalty-structured policy for non-compliance.
- A support-inclined policy to encourage research relevance, strategic partnerships, knowledge transfer mechanism, resource mobilization and concept adaptability and appropriation.
- A compensation-focused policy for compliance and performance and to reward research that 'goes beyond compliance' to mainstream impact on society.

4. <u>Eco-Innovation through Qualitative Research</u>

One of the challenges highlighted in the failures of the Millennium Development Goals was skilled manpower and there is no question that this would also be a challenge in Africa in the sustainability space and in the drive to meet the SDGs. Another huge challenge was the absence of little baseline data on which to build a policy implementation strategy that allows for performance management, monitoring and evaluation. These are the components that qualitative research capacities can mitigate effectively and so the role of academic research institutions as prominent stakeholders in delivering the SDGs cannot be overemphasized. Also, there is great emphasis on innovation and technology-driven models of human capital development to be able to mitigate the enormous skills gaps in African states.

There are over 200 higher institutions in Nigeria (public and private) and Nigerian academics carry out research constantly but most of these gather dusts on shelves or are purely carried out for publication and promotion with little emphasis on research for impact. A critical look at the world patents map paints a sad picture of Africa as almost non-existent in terms of its research output to patents and the utilization of those patents to solve global challenges. This situation is not so different in Ghana, Kenya and Zambia. It doesn't mean that African researchers do not carry out research, but they not carry out research aimed to develop practical solutions to environmental sustainability challenges. As long as this remain the case, there will continually be a critical challenge on our hands in a sustainable world where Africa has a role to play.

A look at the numbers of research papers quoted in an African Development Bank Human Capital Strategy Report for Africa, shows that in the same year that Japan and the US had over 1 million research documents quoted for quality transformational science, Nigeria had less than 40,000 research documents quoted with South African being the highest in Africa with just a little over 100,000 research documents that year.

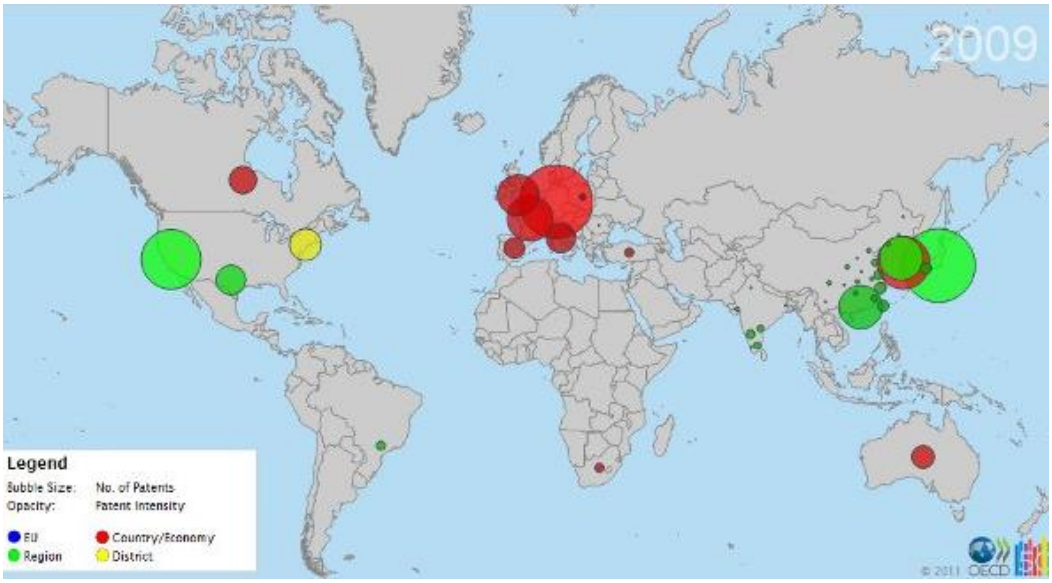

Figure 1. World Patents Map

In as much as the world patents map (Fig 1) do not fully represent the exact picture of innovations in Africa due to the global north-south dynamics with filling patenting, it gives a good indication of the state of Africa's research for impact. It also emphasizes that one of the biggest challenges facing qualitative research for impact in Africa remains the huge gap between academia and industry. This is equally prevalent in the environmental sustainability space. A holistic look at the benefits that bridging the gaps between research and its end users – especially the private sector, compels a focus and emphasizes the need for a national policy framework that guarantees an increased working relationship between research and the private sector in Africa. Eco-innovation could provide a basis for this working relationship.

In an era where the identification of long term 'solutions' to sustainable development and climate change challenges across the world, the African Union Scientific, Technical and Research Commission seems to have also identified the need for countries in Africa to develop home-grown policies and initiatives to allow Africans themselves to provide solutions to their own special needs and challenges. The twin pillars of increasing human capital and building Africa's green economy, come together in **eco-innovation.**

An inclusive green economy will necessitate a shift from low productivity, inefficient and wasteful technologies to efficient and accessible green technologies. Green technologies encompass green systems emphasizing sustainability, resource efficiency or waste and emissions reductions to facilitate or accelerate improvements in economic and social well-being, while minimizing negative impacts on the environment. These technologies are continuously evolving or improving; however, for developing countries, realizing a transition to efficient and cleaner technologies requires deliberate measures that support development and transfer of green technologies, and that accelerate the process of phasing out 'dirty' and obsolete technologies. Green economy can therefore redirect and expand the space for innovation and technology development, so that African countries can remain competitive in the world market.

Eco-innovation has the capacity to deliver the tools needed for Green Growth and sustainable development. Those tools will be commercially successful products, services and technologies that reduce the impacts of human activities on the environment, achieve more efficient/responsible uses of natural resources and enhance societal, economic, and technological resilience to environmental pressures. Genetic engineering, Nano-technological advancements, advanced computer and robotic engineering are some of the emerging technological themes targeted at resolving several human challenges sustainably but these cannot be achieved without a due consideration for innovative and high-output research, a new set of conversations that a new national policy reform should address.

Eco-innovation is essential in making significant and demonstrable progress towards the goals of sustainable societies and economies, including sustainable development. It is the development of commercially successful products, services and technologies that:

- achieve more efficient/responsible uses of natural resources. e.g. management of water, soil for food production, and forestry.
- reduce impacts on the environment e.g. management of urban waste, air pollution in cities, and developing systems for improving the quality of rural and urban water supplies
- enhance societal, economic, and technological resilience to environmental pressures. e.g. engaging in work on community –led sustainable livelihood systems in vulnerable and fragile ecosystems such as drought-affected areas.

Experiences at Lancaster University in the United Kingdom has shown that Universities are key drivers of effective eco-innovation for two reasons. First, they are 'anchors' in co-designing and supporting research-driven eco-innovation partnerships with the private sector which ultimately deliver "environmental solutions". Second, they play the key role in delivering the high level (graduate/post-graduate) skills that are essential to drive forward eco-innovative policies,

products and services. However, exploiting the power of universities to drive African eco-innovation will require significant capacity building to bridge the current, very significant gap between academia and industry in Africa (Fig. 2).

It is with this in mind that there is need for a national policy framework to support the strategic priorities of increasing human capital and building Africa's green economy through bridging the gaps between academia and industry and ensuring that the government-academia-industry cohesion is fundamentally strong in delivering the SGDs in Africa There has been the setting up of Climate Innovation Centers in different parts of Africa and the value is clearly significant in ensuring and promoting sustainability, but the Lancaster University model is such that it has a specialized focus on (i) developing high-level skills and capacity building for eco-innovation within and between universities; (ii) achieving this by strengthening collaboration between universities and research users, especially industry, notably SMEs, building on Lancaster's own experience and proven success through its Centre for Global Eco-innovation (CGE) and iii) building networks both within the African continent, but also with other continents: in Europe, Asia and Latin America.

The Sustainable Development Goals is predicated on a global partnership framework and in a globalized world, significant synergies can emerge through heightened co-operation between eco-innovation centers worldwide. Africa has an important role to play – and indeed faces at present a significant risk in being left behind the rest of the world as the patent graph below illustrates so eloquently.

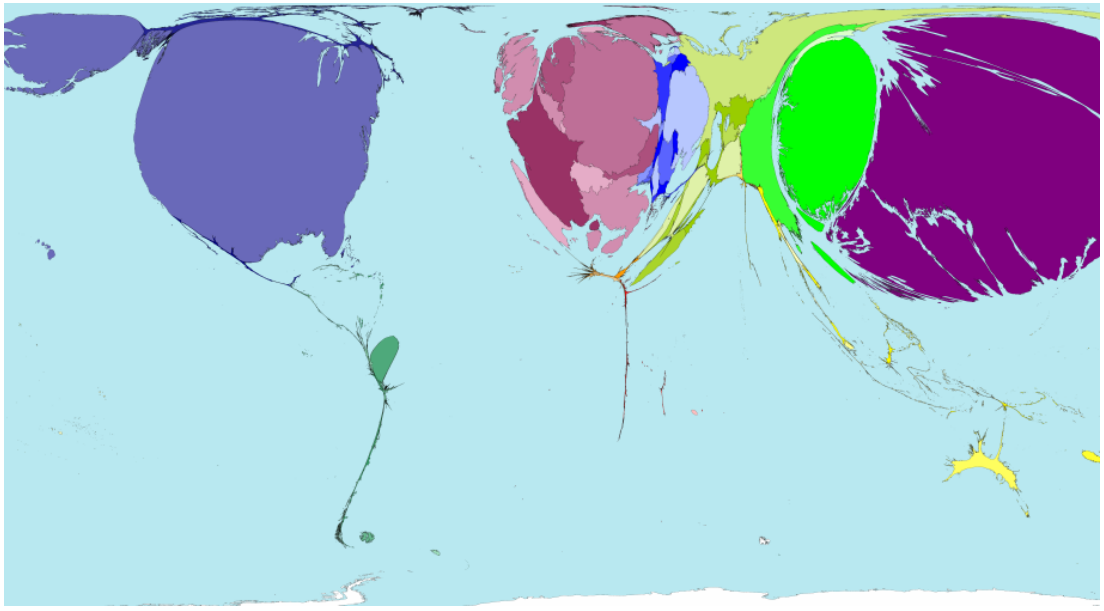

Figure 2 World Patents Map – by utilization

5.0 Conclusion

In Africa, Universities have not figured out how to work with private sector and especially how to tap into the huge revenue resource base that the private sector provides. To put this in

perspective, all the top global Universities that are well funded and have enormous revenue base have gotten full integration into the private sector. Universities like Lancaster, Stanford, Cambridge, MIT etc are so integrated in the private sector that they become the basis for determining the innovation and Africa.

There is however a huge misconception that when there is a reference to private sector engagement, it refers to big multinationals. These multinationals can afford to pay for their research and development activities and mostly they do. However, the untapped resource and strategic partnerships lie with funds-starved small and medium sized enterprises (SMEs) who are abundant and in dire need of the research support from African Universities. They can also provide a basis for student internships and placements.

Some of the eco-innovation schemes that African research institutions and universities should deploy to increase its integration with industry could include:

- Setting up a co-location facilities where industry can rent actual offices for their research and development activities. These offices will be set up using two models namely office space rent (full offices rentals) and hot-desking (renting of small flexible desk spaces for SMEs). However, the basis of co-location should be driven on more than just rent spaces but on mutuality of collaboration between research and industry.
- Design and set up of industry-driven student projects – this is a situation where project proposals are submitted by industry and forms the premises for actual student research and development projects (between 1 month and 1 year type projects). These projects could be undertaken as a full or part of the mandatory research dissertations requirements needed for the awards of Bachelors, Master's degree and even PhD degrees. This provides a basis to make students carry out demand driven research that are readily applicable to provide solutions to actual real-life problems that companies/SMEs face.
- Setting up a University Private Sector Faculty Group – these would involve sending letters of invitation to a wide range of senior executives in top private corporations asking them to join the University Private Sector Faculty Group. They who would deliver some of the actual modules of a wide range of courses in the university.
- Setting up a Collaborative Research Unit – the essence of this unit is to ensure that from the development of proposals for research, to the application for research funds to the implementation of the research itself, there is a constant synergy between academic and research institutions and industry professionals and organisations.

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It is also expedient to acknowledge the incredible contribution and support of staff and personnel of the Centre for Global Eco-Innovation Nigeria, hosted by the University of Benin, Benin City Nigeria.

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Role and Functions of Dietary Phospholipids on Performance of Fish Larvae: A Review

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Abstract

Phospholipid is a general term that includes all lipids containing phosphorus, it has an important role in broodstock spawning, egg, in-turn larval and juvenile quality in marine fish hatcheries. It is an important functional dietary component required for optimal growth, survival, prevention of skeletal deformities and, stress resistance in marine fish larvae and early juvenile.

Dietary phospholipids are not recommended in fish greater than 5 g; at least for salmon and white sturgeon, and recommended levels for marine fish larvae range between 2-12% according to fish species; larvae initial size; feeding period; dietary phospholipid mixture and source, preparation method; basal lipid level, class and fatty acids profile; taking into consideration that quantitative requirements decreasing with larval development.

Key words: *Phospholipids, Marine, Hatchery, Fish, Larvae, Nutrition.*

1.0 Introduction

Fry availability is still a bottleneck of marine aquaculture industry development. As the capture of wild seed for aquaculture is decreasing year after year, the only alternative is the production of fry in hatcheries (Naylor et al. 2000) which relies on a live prey feeding sequence (rotifers and Artemia) that presents several disadvantages such as high cost, low reliability in production, variable nutritional quality and lack n-3 HUFA. In that respect, the main objective in fish larval nutrition is to formulate a compound diet that can be substituted for live prey as early as possible during larval development (Watanabe and Kiron, 1995), which must be attractive enough for the larvae, with suitable diameter to larvae mouth size, and meet the nutritional requirement of marine fish larvae that are sensitive to non-optimal feeding conditions or dietary imbalances, because most tissues and organs are under progressive, intense differentiation and development,

where they do not have enough reserves stored to withstand starvation during this phase (Catalan, 2003; Gisbert et al., 2005). In that respect, Andrades et al. (1996) stated that around 30% of marine fish larvae reared in hatcheries exhibit deformities.

Dietary lipids are: 1) important sources of energy, 2) the only source of essential fatty acids (EFA) needed by fish for normal growth and development, 3) important carriers and assist in the absorption of fat-soluble vitamins (A, D, E and K), 4) lipids, especially phospholipids (PL), are also important for the cellular structure and maintenance of membrane flexibility and permeability, 5) serve as precursors of steroid hormones and prostaglandins, 6) improve feed flavor, and 7) affect diet texture and fatty acid composition of fish.

Lipid requirements of marine fish larvae have been extensively studied during the last 3 decades (Sargent et al., 2002; Bell et al., 2003) and particular attention has been paid to phospholipids (PL) (Kanazawa, 1993; Geurden et al., 1995b; Shields et al., 1999; Izquierdo et al., 2000; Cahu et al., 2003; Gisbert et al., 2005; Seiliez et al., 2006; Tocher et al., 2008), where they verified that marine fish require dietary phospholipids, and this requirement is higher in larval than in juvenile stage. In addition, Sufang et al. (2008) stated that the effect of dietary PL appears to diminish with age and is generally not essential in adults.

2.0 Phospholipids Chemical Composition

Fish oils may be divided into their basic class lipid fraction such as triacylglycerol, diacylglycerol, monoacylgycerol, phospholipids, sterylesters, sterols and free fatty acids. The fatty acid pattern of triacylglycerol and phospholipids of various fish oils showed that they contained highly unsaturated fatty acids.

2.1. Lipid class:

Lipid class refers to the different lipid structures created largely from fatty acids. These include:

- Neutral triglycerides (oil) used for energy storage.
- Polar phospholipids (phosphate head) and glycolipids (glycol head) whose polar nature allows for the construction of cell membranes, which are overwhelmingly composed of these lipids (plus embedded proteins, sterols and some other stuff).
- Non-polar sterols which are also critical to neural cell function and cell membrane function in general.
- Free fatty acids are unattached and “free” to be turned into more complex fatty acids through enzymatic action.
- Other smaller classes include lipid vitamins, carotenoids, messenger lipids and more.

Phospholipid is a general term that includes all lipids containing phosphorus, represent the second largest lipid component after the triglyceride fats and oils (FAO, 1987), which constitute the major component of all cell membranes (phospholipid bilayer). Most phospholipids contain a diglyceride, a phosphate group, and a simple organic molecule such as choline; one exception to

this rule is sphingomyelin, which is derived from sphingosine instead of glycerol. The first phospholipid identified in biological tissues was lecithin, or phosphatidylcholine, in the egg yolk, by Gobley (1847).

Sargent *et al*., (1989) reported that the most common type of phospholipids is phosphoglyceride, which is characterized by a common backbone of phosphatidic acid (PA). He explained that Phospholipids comprise up to 50% of the lipids in biological membranes, where they serve as structural components of the lipid bilayer in cell membranes and regulate membrane fluidity. In addition, he illustrated that the biological membranes of fish contain several categories of phospholipids, primarily phosphatidylcholine (PC) and phosphatidylethanolamine (PE), with lesser amounts of phosphotidylserine (PS), phosphatidylinositol (PI), cardiolipin, and sphingomyelin.

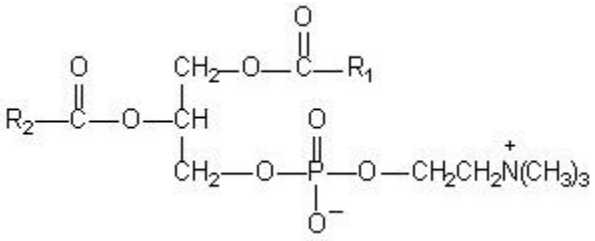
From these structural formulae, it can be seen that the phospholipids, like fatty acids, have a polar region and a non-polar region. However, unlike the fatty acids, the ionic functions are greatly increased by the presence of phosphoric acid and the nitrogenous organic base; which therefore results in combining within the same molecule, both hydrophilic and hydrophobic (fatty acid chain) sites.

Phospholipdis, in conjunction with proteins, form the basic lipoprotein structure of biological membranes. Phospholipids also play important roles as emulsifying agents in biological systems and are particularly involved in the transportation of fats within the body. For example phospholipids may take part in the emulsification of dietary lipids in the digestive tract, and as constituents of high-density lipoproteins in the transport of lipids within the body (Kanazawa *et al*., 1985). Rich dietary sources of phospholipids include eggs and soybean oil.

2.2. Classifications:

The major classifications of phospholipids are:

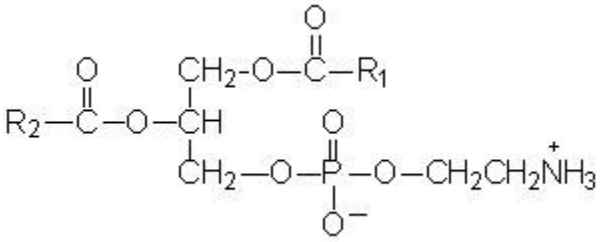
1. Phosphatidylcholine (PC): Lecithin



Adapted from: King (2011)

The term lecithin itself has different meanings when used in chemistry and biochemistry than when used commercially. Chemically, lecithin is phosphatidylcholine. Commercially, the term lecithin refers to a natural mixture of neutral and polar lipids containing a large fraction of phosphatidylcholine. Lecithin is naturally consumed through a diet containing lecithin rich foods such as egg yolk, soybeans, grains, wheat germ, fish, legumes, yeast, and peanuts.

2. Phosphatidylethanolamine (PE): Cephalin



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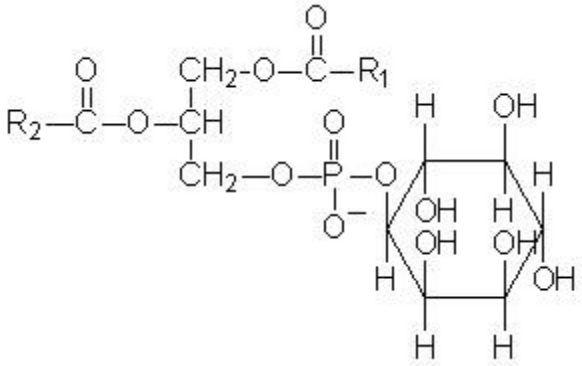
Cephalin is found in all living cells, the principal phospholipid in animals and bacteria; when obtained from vegetable substance contain essentially phosphatidyl colamine, in addition to lecithins. When produced from animal sources, they contain both phosphatidylcolamine and phosphatidylserine.
Source: Author: 2017



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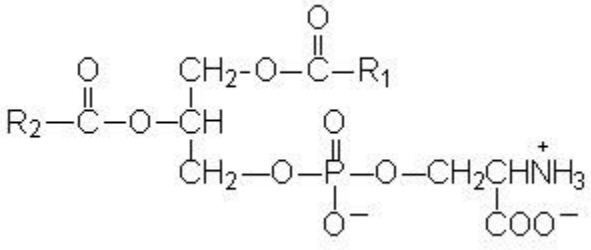
Phosphatidylinositol is an important lipid, both as a key membrane constituent and as a participant in essential metabolic processes in all plants and animals, both directly and via a number of metabolites. It is found in animal (Bovine heart and liver) and plant tissues.

3. Phosphatidylserine (PS)



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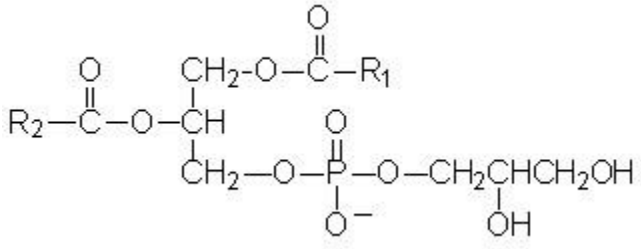
Although phosphatidylserine is distributed widely among animals, plants and microorganisms, it is usually less than 10% of the total phospholipids. PS found in leaves of *Arabidopsis thaliana* while not common in animal tissues.

Phosphatidylserine is an essential cofactor that binds to and activates protein kinase C, involved in the blood coagulation process in platelets and it is a key component of the lipid-calcium-phosphate complexes that initiate mineral deposition during the formation of bone.

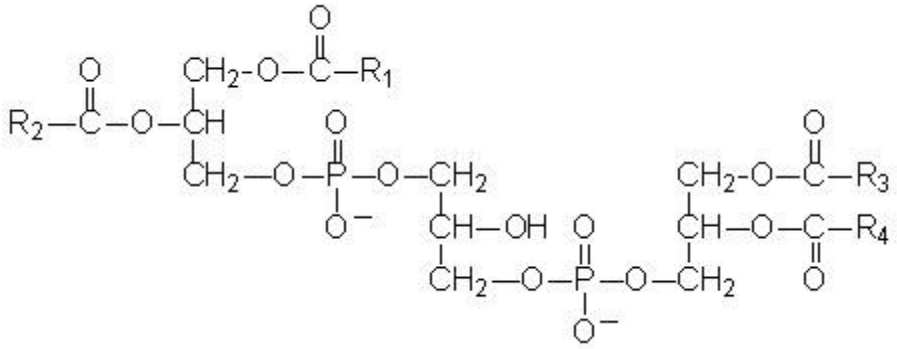
4. Phosphatidylglycerol (PG)



Adapted from: King (2011)

Phosphatidylglycerol is a ubiquitous lipid that can be the main component of some bacterial membranes, and it is found also in photosynthetic membranes of leaf tissue of higher plants and animal membranes where it appears to perform specific functions.

5. Diphosphatidylglycerol (DPG): Cardiolipin



Adapted from: King (2011)

It is found almost exclusively in certain membranes of bacteria (plasma membrane and hydrogenosomes) and of mitochondria of animal, plant and fungi membranes whose function is to generate an electrochemical potential for substrate transport and ATP synthesis.

3.0 Roles of Phospholipids

During the first weeks of marine larvae development, the maturation processes of the gastrointestinal tract can be influenced by nutritional conditions. Several studies have recently demonstrated that the morphogenesis of marine fish larvae could be confused by inappropriate dietary levels of vitamin A (Haga et al. 2002; Villeneuve et al. 2005a) or polyunsaturated fatty acids; PUFAs (Cahu et al. 2003). Different functions and roles of dietary PL for improving fish larval development have been suggested that they are major component of cell membranes, enhance neutral lipid absorption and transport, but they also improve diet quality, mainly palatability, and supply essential components, such as choline and inositol (Tocher et al. 2008).

Phospholipids are considered indispensable for fish larvae, since they distinctly promote the limited ability of larvae to absorb, to re-acylate and to transport triglycerides and provide additional sources of nutrients.

3.1 Improve Larval Growth and Survival

High growth and development rates of the larvae place a premium on providing optimal nutrition so that larval growth, development and survival are maximal.

Lipids are particularly important in fish nutrition not only for supplying calorific energy but also for providing the essential polyunsaturated fatty acids (PUFA) required for embryonic and pre-feeding larval stages (Evans et al., 2000), normal cell membrane function (Sargent et al. 1995b), normal larval growth and development (Sargent et al., 1999).

Studies concerning lipid requirement, and particularly phospholipids, have been initiated by Kanazawa et al. (1981) on ayu where the author (s) reported that fish larvae were incapable of synthesizing PL at sufficient rate to meet the requirement during a period of high cell multiplication; hence PL is required in larval diets. Subsequently, supplementation of microdiets with glycerophospholipids such as lecithin have been found to improve larval growth in red sea bream and knife jaw (Kanazawa et al., 1983a), ayu (Kanazawa et al., 1983b), Japanese flounder (Teshima et al., 1987), striped jack post larvae (Takeuchi et al., 1992), sea bass and turbot post larvae (Geurden et al., 1997c), and gilthead sea bream (Koven et al., 1993; Salhi et al., 1995).

These studies confirmed that marine fish post larvae was stimulated by including intact phospholipids in the diet, and revealed that the growth stimulating effects of phospholipids were due to their fish eggs lecithin which is rich in 22:6 n3 (Docosahexaenoic acid: DHA) and 20:5 n3 (Eicosapentaenoic acid: EPA) fatty acids. Other investigations with red sea bream have also shown that dietary phospholipids also improve quality of eggs (Watanabe et al., 1991a, b).

The most effective PLs in promoting growth and survival were concluded by Kanazawa (1985) who revealed that the positive effects of phospholipids on growth and survival may attributed to either choline or inositol containing 18:2 n-6 (linoleic acid: LA), 18:3 n-3 (linolenic acid: LNA), 20:5 n-3 and 22:6 n-3 fatty acids.

Phosphatidylcholine has a growth promoting effect (Geurden et al., 1997a). It was shown that phospholipids were the more efficient mode of supply for dietary EPA and DHA on Dicentrachus labrax (Gisbert et al., 2005) and Sparus aurata larvae require large amounts of docosahexaenoic acid (DHA, 22:6n-3) and eicosapentaenoic acid: EPA, 20:5n-3 (Izquierdo et al., 2001). In high level of phospholipid the retention of protein increased but the lipid consumed (Ebrahimnezhadarabi et al., 2011). Furthermore, complement of diet with phospholipid is improving the growth of red drum with reducing energy consumption required for phospholipids synthesis (Craig and Gatlin, 1997). Good growth and survival was obtained with sea bass larvae using a compound microdiet containing 11% phospholipids (Cahu et al., 2003).

3.2 Improve Diet Properties

Phospholipids have been shown to exert antioxidant (King et al., 1992; McEvoy et al., 1995; Ishihara (1997), have feed attractant properties (Harada, 1987; Koven et al., 2001), improve diet quality, mainly palatability (Tocher et al. 2008), have been suggested that they may help to reduced leaching of water-soluble micronutrients (minerals and vitamins) from semi-purified diets (Coutteau et al., 1997), and enhance feeding activity and diet ingestion rate (Koven et al., 1998; 2001).

In addition, Saitoh and Ishihara (1997) found choline and ethanolamine the major functional groups in phospholipids, strongly inhibited increases in peroxide values during storage while phosphatic acid derivatives and glycerol did not. On the other hand, PC enhanced feeding activity and diet ingestion rate of micro-diets fed to sea bream larvae up to day 30 post-hatch, which may suggest a role for dietary phospholipids as an age-dependent feed attractant (Koven et al., 1998, 2001). Tocher et al. (2008) reported that the attraction activity of amino acids and their derivatives was ascertained to largely depend on both alpha -carboxyl and alpha -amino groups, but especially the former.

Gisbert et al. (2005) found that sea bass used EPA and DHA more efficiently when these essential fatty acids were present in the phospholipid rather than in the neutral lipid fraction of the diet.

3.3 Improve Digestion

Phospholipids are surface-active agents (surfactants). An earlier maturation of digestive functions was associated with high dietary PL content in sea bass (Cahu et al. 2003) as in pikeperch (Hamza et al. 2008). In addition, Ebrahimnezhadarabi et al. (2011) concluded that adding phosphatidylcholine to (Huso-huso) juvenile's diet up to 4% leads to improvement in food digestion and absorption.

Fish diets do not require the presence of phospholipids as emulsifiers per se, but their presence in the formulation may improve lipid emulsification and aid digestion in the intestine of the fish after consumption (Tocher et al. 2008). Studies of Craig and Gatlin (1997); Kasper and Brown (2003) have shown that dietary phospholipids increased digestibility in juvenile fish. Hung et al. (1997) stated that improved lipid digestibility in salmon fed diets containing soybean lecithin has been attributed to emulsification properties of the phospholipids. Koven et al. (1993) in a study in gilthead sea bream larvae concluded that increasing uptake of dietary lipids when fish fed lecithin–supplemented diet suggested being via improved emulsification. In European sea bass post-larvae, phospholipids supplements also aided the absorption of dietary neutral lipids (Geurden et al., 1997c). According to recent study, Tocher et al. (2008) reported that there is little evidence to support a role for dietary phospholipids as aids to digestion.

Evidence suggests that phospholipids are more easily digested by larval fish compared with triacylglycerols, and their presence may enhance digestion of other lipids in the rudimentary digestive tract of larval fish (Kanazawa et al. (1983a).

3.4. Decrease Skeletal Deformations

A great number of factors, such as genetic or environmental parameters, have been supposed to affect skeletal formation (Divanach et al. 1996). Among these factors, the influence of diet on larval malformation has been experimentally demonstrated. Beside their effects on survival and growth, dietary PL were found to influence the occurrence of skeletal anomalies and stress sensitivity. Kanazawa et al. (1981, 1983b) indicated that laval Plecoglossus altivelis may require phospholipids in their diet to prevent the incidents of malformations, especially scoliosis and jaw deformations. Also, the vitality index of larval rock bream fed 5% SL was three times higher compared to that fed PL-free diets (Kanazawa, 1993).

It has been shown in particular that vitamins (retinol and ascorbic acid) and protein (peptide chain length) can affect skeletal development in marine fish larvae. Cahu et al. (2003) stated that the phospholipid content relative to the total lipid in the diet also influences the skeletal formation process, and they found that a supply of 253 g neutral lipids/kg including 116 g phospholipids/kg led to a very low percentage of deformities. They added that when the phospholipid: total lipid value was lowered, the rate of malformed larvae increased. In addition, Geurden et al. (1998a) stated that phosphatidylinositol prevents deformity in carp (Cyprinus carpio) larvae. Moreover, Cahu et al. (2003) reported that it appears that the malformation rate is more linked to the proportion of phospholipid: neutral lipid than to the overall lipid content in the diet.

Villeneuve et al. (2005b) revealed that high dietary levels of marine phospholipids containing high levels of EPA and DHA induced deformities in sea bass larvae affecting the vertebral column, and disturbed developmental processes when ingested between day 7 and day 40.

3.5. Improve Larval Stress Tolerance

Few studies (Camara, 1994; Kanazawa, 1997; Montero et al. 1999; Weirich and Reigh, 2001) have been conducted to evaluate the effect of phospholipids on stress tolerance of larval fish, and found that dietary phospholipids supplementation can effectively mitigate fish larvae stress. The specific mechanism by which dietary phospholipid supplementation confers stress resistance in larval fish and the class(es) of phospholipids responsible for stress-reducing effects have not been determined, but it is thought that beneficial effects are related to changes in the structure and/or function of biological membranes.

Red sea bream had a higher tolerance for increased water temperature when soybean lecithin (phospholipids) was included in the diet (Kanazawa, 1997). In a study of crowding stress on gilthead sea bream, additional vitamin E seems to protect the complement system against stress-related reduction of activity (Montero et al. 1999). In addition, Weirich and Reigh (2001) indicates that the stress tolerance of larval fish can be improved by feeding diets included proper levels of HUFAs, primarily DHA (22:6n-3), EPA (20:5n-3), and phospholipids, especially PC and PI. In addition, postlarval P. japonicus fed PC-supplemented diet exhibited a higher resistance to salinity stress more that those fed PL-deficient diet (Camara, 1994); this criterion

may be suitable for evaluating the nutritional status of euryhaline fish that adapted to be cultured in different salinities.

3.6. Provision of Essential Components:

3.6.1. Energy and Essential Fatty Acids

Phospholipids can be an important source of energy (fatty acids) in fish, particularly during embryonic and early larval development in species that produce phospholipid-rich eggs (Tocher, 1995). Larval fish at first feeding may be predisposed to digestion and metabolism of phospholipids and the use of fatty acids from phospholipids for energy (Sargent et al., 1997). Dietary lipid is also important source of essential fatty acids (EFA), and phospholipids tend to be a richer source of EFA than neutral lipids such as triacylglycerols (Tocher, 1995). In addition, phospholipids may be superior to neutral lipids as a source of EFA in larval fish due to improved digestibility (Sargent et al., 1997, 1999).

It was shown that phospholipids were the more efficient mode of supply for dietary EPA and DHA to sea bass larvae (Gisbert et al., 2005). There is good evidence that the effects of dietary phospholipids on growth-promotion, survival and the prevention of malformations are not due to the provision of EFA, where soybean lecithin, lacking n-3 HUFA, is effective or more effective than lecithins from marine sources including fish eggs which are rich in n- 3HUFA (Kanazawa et al.,1981,1983a; Geurden et al.,1995b). On the other hand, Villeneuve et al. (2005, 2006) concluded that diets containing very high levels of marine phospholipids and n-3HUFA actually induced skeletal malformations in sea bass larvae.

3.6.2. Phosphorus

Phosphorous is a nutritionally important mineral according to its requirement for growth, bone mineralization, reproduction, nucleic acid synthesis, and energy metabolism (Lall, 2002). Quantitative requirements and deficiency signs include reduced growth and skeletal deformities have been determined for several fish species (Lall, 2002). Feed is the main source of phosphorous, mainly from meals or premixes, with meat/bone meal, fish meal, plant meals, as phosphate is low in aquatic environments (non-polluted). Bioavailability varies, but generally the inorganic (calcium and potassium salts) and organic (phospholipids) forms found in fish meals are more readily available to fish than the phytates (phytic acid salts) found in plant meals (Lall, 2002). Effects of dietary phosphorus and phospholipid level on growth and phosphorus deficiency signs were investigated in juvenile (1 g) Japanese flounder (Uyan et al., 2007). The results showed that there was no interaction between dietary phosphorous and phospholipid, suggesting that supply of phosphorous was not a mechanism for the growth promoting effects of dietary phospholipids.

3.6.3. Choline and Inositol

It is known that choline cannot be synthesized in animals (Lykidis, 2007), but there may be evidence that some inositol can be synthesised in carp intestine and channel catfish (Halver, 2002). However, both choline and inositol are regarded as vitamins for fish, as there are known deficiency signs for both, and quantitative requirements for growth have been defined, at least

for choline (Halver, 2002). Both choline and inositol are quite ubiquitous in feed ingredients including wheat germ, fish and plant (bean) meals, but they are often supplemented in vitamin premixes.

4.0 Functions of Phospholipids

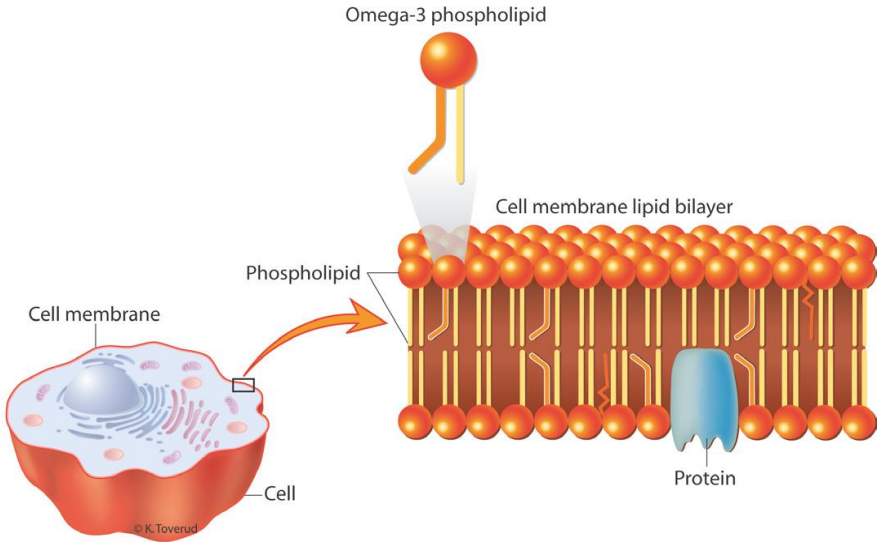


Figure 1 Cell membrane

4.1 Protect Cell Membrane

Cell membranes are vital for the proper functioning of fish body (Fig 1). The cell membranes are made up of three components; these include phospholipids, glycolipids, and cholesterol. Phospholipids are the largest component of the three. Phospholipids are made up of saturated and unsaturated fat. Phospholipids have a very big role in protecting the structure and function of cell membrane (Tocher, 2003; Kanazawa, 1985). The most part of phospholipid membrane functions is maintenance of the differential distribution of solutes between the extracellular and intracellular fluids. This membrane is semi-permeable, allowing for only certain substances to enter or leave the cell. Much of the phospholipid membrane's functioning is owed to the membranes permeability and its ability to move fluently.

The dynamic changes in the composition and metabolism of the phospholipids in biomembranes in response to environmental factors, especially temperature, have been reviewed (Hazel and Williams, 1990; Hochachka and Mommsen, 1995).

4.2 Lipid Emulsification and Transport

Phospholipids also have an important structural role in the digestion of lipids as they are essential in emulsifying dietary lipids along with bile salts (Olsen and_Ringø, 1997). Fish bile can contain variable amounts of phospholipid, usually PC is the major phospholipid in fish bile and it is thought that biliary phospholipid has two roles in the bile (Fig. 2); solubilises biliary cholesterol and protecting biliary tract epithelium from the cytotoxic effects of bile salts (Moschetta et al., 2005).

Phospholipids, constituents of the cell membranes, are structural lipids. Successful first feeding with diets incorporating high levels (12%) of vegetable phospholipids (supplied as soybean lecithin) has been reported in European sea bass larvae (Cahu et al., 2003). Growth and normal morphogenesis increased as the dietary inclusion of phospholipids increased, and it is possible that different classes of phospholipids have specific physiological roles. Phospholipids have emulsifier property that causes increase of digestion of neutral lipids (Kasper and Brown, 2003), and have important role on transport of lipid particularly fatty acid (Fontagne et al., 1998).

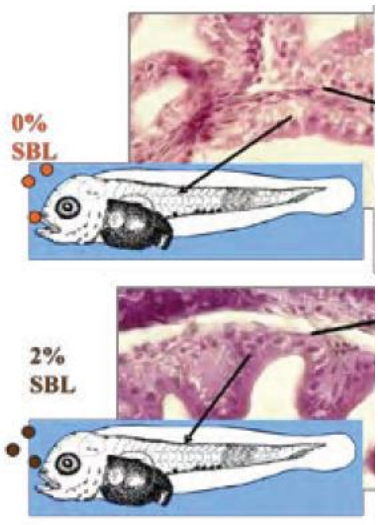


Figure 2
Inclusion of different types of phospholipids in larval microdiets markedly enhance reacylation, lipoprotein synthesis and lipid transport (Izquierdo, 2004).

4.3 Regulation of Metabolism and Physiology

Phospholipids are important precursors for a range of highly biologically active mediators of metabolism and physiology including eicosanoids, diacylglycerol, inositol phosphates and platelet activating factors (PAFs). Phospholipids are the source of the substrate fatty acids for the formation of eicosanoids, a range of bioactive derivatives of highly unsaturated fatty acids (HUFA), especially arachidonic acid (ARA) and eicosapentaenoic acid (EPA). The distribution and production of eicosanoids in fish species and tissues and their possible roles have been reviewed (Sargent et al., 1989, 2002; Tocher, 1995, 2003).

4. 4 Platelet-Activating Factor (PAF)

Platelet-activating factor is a biologically active phospholipid synthesized by inflammatory cells and a potent mediator of many leukocyte functions, including platelet aggregation, inflammation, and anaphylaxis (Snyder, 1987). Synthesis of PAF has been demonstrated in rainbow trout (Turner and Lumb, 1989) and PAF acetylhydrolase activity has been reported in fish serum (Cabot et al., 1984).

4.5 Energy Production

Any lipid class containing fatty acids can act as a source of energy, which is released through β-oxidation of the acyl chains producing acetyl-CoA and NADH that are further metabolized via

the tricarboxylic acid cycle and oxidative phosphorylation, respectively. Phospholipids can serve as a source of energy in fish in certain circumstances, such as embryonic and early larval development. Upon hatching, the larvae of many fish species have immature mouth parts and intestinal tract, unable to commence exogenous feeding immediately. Therefore, throughout embryogenesis in the egg and then during early larval development up to first feeding, the larvae gain nutrition from endogenous energy reserves in the yolk. Essentially there are two main types of fish egg, those with oil globule (s) having relatively high levels of neutral lipids (20–50% of egg total lipid), and those without oil globule having low levels of neutral lipids (about 15% of total lipid) and consequently, high levels of phospholipids, predominantly PC (Wiegand, 1996; Salze et al., 2005). These data show a decrease in the absolute amount of phospholipid, usually PC, during embryogenesis and early larval development, particularly in phospholipid-rich marine fish eggs. A possible consequence of complete catabolism of phospholipid for energy would be the loss of important PUFA. Ronnestad et al. (1995) found 40% of the DHA, important fuel in halibut eggs, being catabolized.

5.0 Phospholipids Requirements

Marine fish contain large amounts of docosahexaenoic fatty acid: DHA (22:6 n-3) and eicosapentaenoic fatty acid: EPA (20:5 n-3) in the phospholipids of their cellular membranes, they can neither biosynthesize 22:6 n-3 de novo nor from shorter chain precursors such as 18:3 n-3. Therefore, 22:6 n-3 and 20:5 n-3 are essential dietary constituents for marine fish. DHA is the major constituent of the structural phospholipids of cell membranes in fish, involved in producing eicosanoids and arachidonic acid (20:4 n-6) is the major precursor of eicosanoids (Sargent et al., 1997, 1999).

Some species of fish may have only a limited capacity to synthesize phospholipids de novo in early stages (Coutteau et al., 1997), in turn many fish larvae receive an abundance of phospholipids in their natural diets, whether from yolk sac lipids prior to first feeding or from natural prey and after first feeding from inert food. The very high growth of fish larvae (10-30 and up to 100%/day) means higher requirements in terms of amino acids (AAs), highly unsaturated fatty acids (HUFAs), phospholipids (PLs) and other nutrients (Conceição et al., 2007).

5.1 Quantitative Requirements

The stimulating effects of phospholipids in larval fish growth are attributed to its severe shortage meeting requirements (Coutteau et al., 1997; Fontagné et al., 1998; Geurden et al., 1999). The ideal marine fish larval diet is one containing circa 10% of the dry weight as n-3 HUFA-rich, marine phospholipids with less than 5% triacylglycerols, as exemplified by the lipid compositions of marine fish egg yolk, marine fish larvae themselves and their natural zooplankton prey (Sargent et al., 1999). Quantitative requirements decreasing with development, at least from larvae to small juveniles and no requirement has been observed in fish (at least salmon and white sturgeon) of greater than 5 g (Tocher et al., 2008).

5.2 Qualitative Requirements

Essential dietary nutrients and phospholipids have been investigated for different species of marine fish larvae (Table 1). All of these preparations are vary proportions mixtures of different phospholipid classes mainly PC, PE, PI and PS. For instance, SL can contain 50–86% phospholipid, with typically around 20–25% each of PC, PE and PI (Izquierdo and Fernandes-Palacios, 1997).

Nutrient	Species	Reference
Fatty acids	*Pagrus major* *Sparus aurata* *Psetta maxima* *Paralichthys olivaceous*	Izquierdo *et al*., 1989a Rodriguez *et al*., 1994 Gatesoupe and Le Milinaire, 1985 Izquierdo *et al*., 1992
Vitamine (E) Phospholipids	*Sparus aurata* *Pagrus major* *Paralichthys olivaceous*	Koven *et al*., 1993; González *et al*., 1995 Kanazawa *et al*., 1983b Teshima *et al*., 1987

Table 1 Essential nutrients in diets for marine fish larvae
Adapted from: Izquierdo and Fernandes-Palacios (1997)

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5.3. Factors affecting Phospholipids Requirement

5.3.1 Natural Food Availability and Type

In that respect, Sargent et al. (2002) reported that in natural environment, larvae ingest live feed whose lipid is predominantly phospholipids, thus it will be seldom required to biosynthesise phospholipids extensively de novo, which is consider an indication to the importance of phospholipids for marine fish larvae feeds in aquaculture.

5.3.2 Phospholipids Source and Level

Quantitative requirements of phospholipids have generally been reported in terms of levels as a percentage of the diet by weight. Accordingly, Kanazawa et al. (1983a) reported 3% dietary requirement of soybean PC for Ayu larvae when pollack liver oil was used as the basal lipid source. In addition, Sargent et al. (1999) reported that the ideal diet for marine fish larvae would include 10% marine fish phospholipid, since egg or yolk sac larvae exhibit 10% phospholipid concentration. Moreover, Cahu et al. (2003) found that a diet containing 19% lipids including almost 9% phospholipids induced a good growth in first feeding larvae of European sea bass. Also, for sea bass larvae, (Ambasankar et al., 2009) revealed that good growth and survival have been obtained when the larvae fed 5 and 10% fish oil and lecithin containing diets, respectively. In another study, Ebrahimnezhadarabi et al. (2011) found 4% level of phospholipids improves the growth of beluga juveniles especially in early days. On the other hand, increasing dietary phospholipids level beyond the required level did not affect survival or growth in various studies (Conklin et al., 1980; Kanazawa, 1993).

5.3.3 Fish Species and Life Stage

Under practical farming conditions, in spite of being still needs confirmation, true dietary phospholipids requirement had been suggested by Teshima et al. (1986b) as a specific

requirement for fatty acid transport and/or phospholipids biosynthesis which have slow rate in relation to metabolic demand during the larval growth phase. The major fatty acids in the lipids of marine fish eggs such as gilthead sea bream are docosahexaenoic (DHA), palmitic, eicosapentaenoic (EPA) and oleic acid, the relative importance of each fatty acid differ markedly among species or even between different egg batches of the same species (Mourente and Odriozola, 1990). According to life stage, PL requirement decreases with age or developmental stage as shown with rock bream, where required levels decreased from 5% to 3% of soybean lecithin from larva to juvenile stage (Kanazawa, 1993). It is clear also that PL requirements differ between species as shown in Table 2.

Species	Initial size	Test period	PL Source	Basal diet	PL level (% diet)		Author
					Optimal	Other tested	
Fish larvae							
Plecoglossus altivelis	2.4 mg WW	20 days	EL or SL	Casein	3% (G.S.M)	0	Kanazawa *et al*. (1981)
Chrysophrys major	4.8 mm TL	20 days	SL	Casein/gelatin	5% (G.S)	0	Kanazawa *et al*. (1983a)
Oplegnathus fasciatus	6.0 mm TL	22 days	SL	Mixture of various proteins	7.4% (G.S)	0, 2.5, 5	Kanazawa *et al*. (1983a)
Plecoglossus altivelis	9.6 mm TL	50 days	PL EL SL	Casein	3% (G.S.M) 3% (G.S.M) 5%(G.S), 3% (M)	0 0 0, 1, 3	Kanazawa *et al*. (1983a)
Oplegnathus fasciatus	26 mg WW	28 days	SL (53% POL)	Mixture of various proteins	5 (G.S.R)	0, 3, 7	Kanazawa (1993)
Paralichthys olivaceus	4.6 mm TL	30 days	SL (53% POL)	Casein	7 (G.S)	0, 3, 5	Kanazawa (1993)
Dicentrarchus labrax	Larvae	40 days	3, 6, 9 and 12% SL	-	12% (G,S,M)	0	Cahu *et al*. (2003)
Sparus aurata	Larvae	23 days	9, 11 and 15% SL	-	9% (G.S)	0	Seiliez *et al*. (2006)
Sander lucioperca	Larvae	24 days	1, 5 and 9% SL	-	9% (G)	0	Hamza *et al*. (2008)
Fish juvenile							
Acipenser transmontanus	5-10 g WW	42 days	SL (75% PL)	Casein	0	8	Hung and Lutes (1988)
Dicentrarchus labrax	3.54 g DW	40 days	SL (65% PL) EPC (95% PC) SPC (95% PC)	Mixture of various proteins	3 (G) 2 (G) 2 (G)	0 0 0	Geurden *et al.* (1995b)

Table 2 summarized PL levels reported to be optimal for several larval and juvenile fish.
Adapted from: Tocher et al. (2008); Izquierdo and Hernández-Palacios (1997)

KEY:

DW: dry weight	WW: wet weight	TL: total length
G: growth	S: survival	R: stress resistance
M: malformations		
PL: total phospholipids	SL: Soybean lecithin	EL: Egg lecithin
PC: Phosphatidylcholine		

POL: total polar lipids, expressed as (%) of total lipids
EPC: Egg phosphatidylcholine
SPC: Soybean phosphatidylcholine.

5.3.4. Phospholipid Class

In the few studies in which comparisons are possible, both PC and PI were effective in meeting phospholipid requirements in larval ayu whereas PE was less effective (Kanazawa, 1983b; Kanazawa *et al*., 1985). In Japanese flounder larvae, growth improved with PC, but not with PI or PE (Kanazawa, 1993). However, it is possible that different phospholipid classes may play slightly different roles and thus have different effects in different species (Kanazawa, 1983a).

5.3.5. Dietary Lipid and Fatty Acid Profile

Dietary sources of DHA, EPA and ARA are considered essential for larval survival, growth and normal development, where dietary lipids are the main energy and fatty acids sources needed for the synthesis of new cellular structures. High dietary lipid level improved sea bass (*Dicentrarchus labrax*) development and larvae have a high capacity to utilize phospholipids (Zambonino Infante and Cahu, 1999). In the past, it was argued that the ideal diet for fish larvae is the yolk of eggs or yolk sac larvae, whereas the lipid content and composition of marine fish eggs is essentially the same as that of the resulting larvae and also of the larvae's natural copepod diet. One of the principal factors affecting the nutritional value of live prey organisms was their EFA content (Watanabe *at al*., 1983). Copepods contain high level of 22:6*n*-3 while lowest level of 20:4*n*-6; *Artemia* nuplii appear to be the poorest in both fatty acids as shown in Table 3.

	22:6*n*-3	**20:5*n*-3**	**20:4*n*-6**	**18:3*n*-3**	**18:2*n*-6**	**18:1*n*-9**	**16:0**
Cod eggs	29.3	14.8	1.7	0.3	1.1	11.5	18.5
Cod larvae	30.2	15.0	1.8	0.6	1.7	7.6	17.4
Calanoid copepods	32.2	12.1	1.0	1.7	2.0	7.0	18.1
Artemia nuplii	0.0	3.9	1.1	22.1	5.9	17.4	11.6
Artemia nuplii + TOO	19.4	10.8	3.0	14.2	5.7	24.4	16.7

Table 3 Comparison of fatty acid composition (wt. %) of total lipid from fish eggs, larvae and live larval feeds. Adapted from: Sargent et al. (1999b).

Many marine fish eggs, cod being a typical example, have phospholipid as their major lipid constituent, consisting of circa 10% of the total egg dry weight, with triacylglycerols usually as a minor component at less than 5% of the egg dry weight (Table 4).

100 g dry wt of diet contain 10.0 g total phospholipid
10.0g total phospholipid contain 0.42 g phosphatidylinositol 0.42 g phosphatidylinositol contain 72 mg (0.40 mmol) inositol
10.0g total phospholipid contain 6.34 g phosphatidylcholine 6.34 g phosphatidylcholine contain 624 mg choline
10.0g total phospholipids contain 1740 mg 22:6*n*-3 and 949 mg 20:5*n*-3, i.e., 2699 mg of *n*-3 HUFA, and 118 mg (0.39 mmol) 20:4*n*-6
Ratio of 22:6*n*-3 : 20:5*n*-3 : 20:4*n*-6 in Diet is 183 : 100 : 12
Ratio of *n*-3 HUFA: *n*-6 HUFA is 24: 1

Table 4 Amounts of essential fatty acids, inositol and choline in a diet containing 10% dry weight as marine fish Phospholipida
Adapted from: Sargent et al. (1999b).

5.3.6. Environmental Factors (Temperature)

There is no doubt that environmental factors and nutritional factors affect fish larvae physioliogical condition. Thus, fish larvae need certain nutrients to resist certain environmental factors. Accordingly, soybean lecithin (phospholipids) concluded to be important for red sea bream to resist higher water temperature (Gannam and Schrock, 2001), arachidonic acid (ARA) levels in marine fish larvae may be important for stress tolerance (Bell and Sargent, 2003) and live food containing high n-3 HUFA in white fish (*Rutilus frisii kutum*) diet could increase larval resistance to pH stress (Gholami, 2010).

6.0 Dietary Phospholipids and Sustainability

6.1. Sustainability

Paradoxically, aquaculture diets have been based traditionally on fish meals and oils derived from industrial feed-grade or reduction fisheries, as the predominant protein and lipid sources (Sargent and Tacon, 1999; Pike, 2005). Intensive farming, which based largely on carnivorous marine species that need high quality of feeds, lead to rapid and increasing demands for aquaculture feeds especially as the current estimates requirements for aquaculture feeds could exceed global supplies of fish oil and fish meal within the next years (FAO, 2006). Therefore, if aquaculture has to continue expand and supply more global demand for fish feeds, alternatives to fish oil and meal must be found (Barlow, 2000; Tacon, 2004). The only obvious and sustainable alternative to marine meals is plant meals, which contain very little phospholipid in comparison with fish meals (Sargent *et al*., 2002). Therefore, replacing fish meal with plant meals will arises for great reduction in dietary phospholipid concentrations, which means that possible phospholipid requirements may become an important and significant issue in the future, especially when marine fish larvae production face nutritional problems such as accumulation of lipid droplets reported in the hindgut of juvenile gilthead sea bream fed plant proteins and fish oil based diets (Caballero *et al*., 2003; Sitjà-Bobadilla *et al*., 2005) and in the gastrointestinal tract of salmonids fed vegetable oils, the situation which was reversed using phospholipid supplementation (Olsen *et al*., 2003). Liver steatosis was also observed in gilthead sea bream fed plant meals (Sitjà-Bobadilla *et al*., 2005) or vegetable oils (Caballero *et al*., 2004; Wassef *et al*.,

2007). There is some evidence that soybean PC may alleviate similar signs of liver disease in animal studies (Ipatova *et al*., 2004). Therefore, dietary phospholipid supplementation may be beneficial in larger (on-growing juvenile or adult) fish particularly when fed diets high in plant meals.

6.2. Dietary Sources of Phospholipids

6.2.1. Oils

The phospholipid contents of both fish and vegetable refined oils are very low as they are removed during the normal refining processes. Crude soybean oil contains around 1.5–3.1% total phospholipid (soybean lecithin); 13–18% PC, 10–15% PE, 10–15% PI and 5–12% PA, while crude sunflower oil has 0.5–1% total phospholipid and is also used to produce lecithin having similar phospholipid class profile to soybean lecithin, and most other crude vegetable oils (rapeseed/canola lecithin) have less phospholipid, up to about 0.5% total phospholipid (Daniel, 2004).

6.2.2. Meals

Unless rather crude oils are used, the vast majority of phospholipids in fish diets will be provided by meals and other essentially protein components. The following are some types of meals that provided phospholipids:

6.2.2.1. Fishmeal

Residual lipid contents in fish meals can be reasonably high, varying from 5–13% of weight, with a triacylglycerol/phospholipids ratio of around 2:1 (De Koning, 2005). In fish feeds, phospholipids estimated 5–25% of the total lipid depending on lipid content and formulation of the feed, and analytical method used (Johnson and Barnett, 2003). Individual phospholipid class reflect the phospholipid composition; PC, PE, PS, PI, PA (Tocher, 1995). Generally, most plant meals have much lower levels of residual phospholipids, mainly due to the original products (seeds/beans etc.) having much lower phospholipid contents. However, full-fat soybean meal has the highest levels of lipid (about 20–25%) with only around 0.3–0.6% phospholipids, primarily PC, PE, PI and PA. On the other hand, defatted soybean meal has about 1% lipid. More information is needed to define phospholipids contents and compositions in other plant meals to be available for feed formulation.

6.2.2.2. Soybean

Soybean is the primary natural, consistent, superior feed ingredient that is an excellent source of dietary phospholipids (known as soybean lecithin), the most economically valuable component in soy oil, which comprises approximately 20% of its dry weight, the average composition of phospholipids in crude and refined soybean oils is 1-3 and 0.3%, respectively (Lim and Akiyama, 1992). This compound has been reported to be a dietary essential for marine shrimps and marine fish larvae (Lim and Sessa, 1995).

Soy lecithin: Maurice Gobley first isolated the substance in harry yolks that enabled water and oil to mix and named his discovery Lecithin, after the hellenic word `lekithos,' meaning `yolk of egg' (Quinn. 1992).

Soybean lecithin (soy phosphate) is a mixture of neutral and polar phospholipids, contains PC, PE, PI and PA. Soybean lecithin is a natural-sourced, consistent, superior feed ingredient that is an excellent source of dietary phospholipids (Poston, 1991). Aquaculture species efficiently absorb and utilize the biologically active nutrients in lecithin, the use of which can reduce the nitrogenous waste that can elevate biological oxygen demand levels and hamper performance (Paibulkichakul *et al*., 1998). On the other hand, Hamza *et al*. (2011) concluded that PL from plant origin (soybean lecithin) was as efficient as those from marine fish origin for pikeperch larvae, for which the main phospholipid source used in compound diets is soybean lecithin.

Advantages of Lecithin:

- Improves survival rate of shrimp and fish larvae
- Improves growth rate of fish and shrimp
- Improves feed utilization efficiency
- Increases resistance to stress
- Provides a consistent source of bio-available phospholipids
- Good energy source
- Mobilizes cholesterol
- Nutritionally superior source of choline, inositol and unsaturated fatty acids
- Reduces the leaching of water-soluble nutrients
- Acts as a natural antioxidant
- Acts as a feed attractant

6.2.3. Live Prey (Copepods)

Besides being an excellent natural feed, which have a nutritional profile that matches the requirements of marine finfish larvae, copepods are a rich source of phospholipids, of essential high unsaturated fatty acid (HUFA) and of normal antioxidants (Sargent *et al*., 1997). As much as 90% of the total fatty acids present in copepods are more easily used form these phospholipids (Cortney *et al*., 2009). Marine copepods are superior to enriched *Artemia* as food for halibut larvae in terms of survival, eye development and pigmentation, and this superiority can be related to the level of DHA in the feed. Marine copepods are rich in carotenoid pigments (8.2–43.6 mmol astaxanthin/g lipid, whereas *Artemia* contain lower quantities of the related carotenoid (4.5–5.9 mmol canthaxanthin/g lipid for the enriched *Artemia*) (Shields *et al*., 1999).

6.2.4. Microalgae

Since 1995, it has refined marine microalgae concentrates of traditional algal species for use in commercial aquaculture for its phospholipid composition and high quality protein. The microalgae are either used for conditioning of larval tank water, as feeds for *Artemia* and copepods or as live feeds themselves. Typically, over 60% of lipids in these algae are

phospholipids, sterols and other membrane lipids, only 1/3 of lipids are triglyceride oil; also phototrophic algae have a very high protein to lipid ratio (Schwartz *et al*., 2008).
Microalgae production is based on a few species chosen from several families held in small-scale stock cultures including *Chaetoceros* and *Skeletonema* (Bacillariophyceae), *Cryptomonas* (Crytophyceae), *Tetraselmis* (Prasinophyceae), *Isochysis* (Haptophyceae), *Pavlova* (Prymnesiophyceae), *Nannochloropsis* (Eustigmatophyceae) and *Heterocapsa* (Dinophyceae) (Hall *et al*., 2004).

7 .0 Summary and Discussion

The role of nutrition in larval performance remains a key goal in improving the efficiency of production systems. Inclusion of intact phospholipids in fish diet has been reviewed through various studies during last three decades. Passing through Role and Functions of Phospholipids, the importance of this dietary component for marine fish larvae during the weaning period and first feeding has turned out, especially with knowing the very high mortalities percentage in marine hatcheries, which constitute the main constraint facing marine aquaculture expanding.
According to Nikolsky (1963), physiological condition of fish depends mainly upon three factors; genetical, environmental and nutritional factors. Owing to: 1) marine fish larvae have very high metabolic rate (10-30 and up to 100%/day), 2) have limited capacity to synthesize phospholipids *de novo*, 3) have limited sources of phospholipids from natural food according to their mouth size, 4) have immature mouth parts and intestinal tract, 5) most larval tissues and organs are under progressive, intense differentiation and development, 6) lacking common used live pries (rotifers and *Artemia*) in hatcheries to phospholipids, 7) high cost of using live prey, low reliability in production, variable nutritional quality and lack *n*-3 HUFA, 8) around 30% of marine fish larvae reared in hatcheries exhibit deformities; it becomes necessary to formulate of compound diet (attractive, suitable to larvae mouth size, and meet the nutritional requirement of marine fish larvae) that can be substituted for live prey as early as possible during larval development, for they are sensitive to non-optimal feeding conditions or dietary imbalances, where they do not have enough reserves stored to withstand starvation during this phase.

On the other hand, phospholipids were found to overcome most of the obstacles could face marine fish larvae in hatcheries either during weaning period or at the beginning of first feeding, due to its advantages: 1) improve larval growth and survival, 2) improve diet properties, 3) improve digestion, 4) decrease skeletal deformations, 5) improve larval stress tolerance, and 6) provision of essential components (energy, essential fatty acids, phosphorus, choline and inositol).

As for nutritional requirements of phospholipids for marine fish larvae, it will be according to: 1) phospholipids source, level, class, lipid content and fatty acid profile will be selected in accordance to fish species feeding behavior, 2) nature, type and chemical composition of ingredient, 3) fish life stage, 4) water quality (chemical and biological), 5) phospholipid fatty acids profile, 6) natural food available in the surrounding water, 7) balance between saturated, monounsaturated and polyunsaturated fatty acids in dietary ingredients, 8) balance between dietary protein content and phospholipids, and 9) cost effective in commercial scale hatcheries.

Conclusion

Intact phospholipid has an important role in broodstock spawning, egg, in-turn larval and juvenile quality in marine fish hatcheries. It is an important functional dietary component required for optimal growth, survival, prevention of skeletal deformities and, stress resistance in marine fish larvae and early juvenile.

Various studies have shown the beneficial effects of dietary PL for marine fish larvae. Fish used EPA and DHA realized better performance when these essential fatty acids were presented in the phospholipid rather than in the neutral lipid fraction of the diet. Lipid and LC-PUFA are generally provided by fish oil, which is a neutral lipid, but marine phospholipid would be a nutritionally better source of LC-PUFA.

Nevertheless, further research using microdiets and different PL sources is still needed to identify the nutritional value of PL, optimal dietary source and level, interaction of PL with other nutrients such as protein, which may be instrumental improve the nutritional requirements of marine fish larvae in hatcheries.

Another role and function for PL in euryhaline fish larvae acclimatization is needed to be investigated in order to maximize hatchery production of these species for supplying fish farms. Finally, does using organic oils carriers, such as sweet almond; apricot kernel; jojoba and wheat germ with animal lipid sources may optimize the nutritional value and absorption of phospholipids?

Recommendations

In the shadow of being not demonstrated in fish greater than 5 g (at least for salmon and white sturgeon), phospholipids requirement levels for marine fish larvae recommended to be between 2-12% according to fish species; larvae initial size; feeding period; dietary phospholipid mixture and source, preparation method; basal lipid level, class and fatty acids profile; taking into consideration that quantitative requirements decreasing with larval development.

Glossary

Phospholipids: Compounds associated with molecular organization of cells, particularly membranes, composed mainly of fatty acids, a phosphate group, and a simple organic molecule.
Phospholipid bilayer: A structure, such as a film or membrane, consisting of two molecular layers.
Esterification: A reaction of an alcohol with an organic acid to produce an ester and water.
Lecithin: is a generic term to designate any group of yellow-brownish fatty substances occurring in animal and plant tissues, and in egg yolk, composed of phosphoric acid, choline, fatty acids, glycerol, glycolipids, triglycerides, and phospholipids (e.g., phosphatidylcholine, phosphatidylethanolamine, and phosphatidylinositol).

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