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Digitalization in Agriculture, Food and Nutrition - A Case Study of Nigeria

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The participation of ICT-enabled service providers is gratefully acknowledged. Kitovu and Famrcrowdy granted institutional interviews, while ThriveAgric and E-Farms granted the study team access to their farmers. A video documentary with farmers was facilitated by ThriveAgric at its site in Shika, Giwa Local Government Area, Kaduna State.

Executive summary

Optic fibre infrastructure offers huge Internet broadband (IBB) capacities. However, Internet broadband penetration in Nigeria is still miserably low. For several factors, Internet access today in Nigeria is 99% by wireless mobile networks. There is a general absence of government's nationwide direct investment in optic fibre cable infrastructure. Such investments in partnership with the private sector would have reduced retain end Internet access cost.

By 2016, 93% of the urban respondents, 86% of the rural respondents and 89% of the full sample had access to mobile phones. By March 2016, there were 92,424,736 Internet subscribers in Nigeria. Comparing 2016 and 2010, urban internet access moved up to 29% from 11.6%; rural internet access increased from 1.5% to 9.8% and the national internet access increased from 3.6% to 17.4%. The top use of the Internet was to send/receive emails among the urban (46.3%), rural (45.0%) and all (45.8%) users. The use of Internet for banking services was a dismal result among urban (0.4%), rural (0.5%) and all (0.4%) users.

The Federal Ministry of Communications (FMC) formulates policy on communications, while the Nigerian Communications Commission (NCC) implements policies on telecommunications. Numerous challenges have slowed the growth of the telecom infrastructure in Nigeria, namely, high cost of the right of way, multiple regulatory bodies, lengthy processing of right of way, conflicting agreements at federal and state levels with operators, cable theft and road works leading to damages to fibre installations/infrastructure, erratic grid electricity supply, fragile backbone infrastructure and limited investment in IBB industry.

Four case studies were implemented, two at organizational levels and two at the end-users level. The organizational interviews were granted by Kitovu and FarmCrowdy. Some of the key results from the ICT4Ag case studies were:

Strong emphasis on youth empowerment and participation in ICT-enabled services (Kitovu)

Strong emphasis on farmer organizations/ groups as platform for service delivery and capacity building/ training (Kitovu, FarmCrowdy, ThriveAgric, E-farms)

Emphasis was mostly on data collection and other services, including connection of smallholders to input sources, product processors and off-takers (Kitovu, Farmcrowdy)

Data collection used mainly global positioning system (GPS), satellites, sensors, camera , mobile phone and smartphone apps (Kitovu, Farmcrowdy)

Reduction in postharvest losses due to market linkages (Kitovu)

Smallholders were poorly linked to credit, while service provided had no own funds to on-lend (Kitovu). Changing government agricultural policies with successive administrations (Kitovu)

Online partnership with Produce buyers, smallholder farmers, investors, input sellers, insurance companies, investors, commercial farmers, and graduate farmers (Farmcrowdy)

Poor access of farmers to smartphones, poor network connectivity in rural areas and language barrier (Farmcrowdy). Smallholder access to ICT-enabled linkages to product markets indicated by 9/10 farmers interviewed (ThriveAgric) 9/10 farmers had knowledge of ICT devices used for service delivery (ThriveAgric). Preliminary evidence has shown income increase among small crop and aquaculture farmers, arising from ICT services; however, further work will be needed to link the gain in income to specific services and /or ICT devices (ThriveAgric; E-farms)

Preliminary evidence has shown output increase among small crop farmers arising from ICT services; however, further work will be needed to link the gain in output to area or yield or both; and to specific services and /or ICT devices (ThriveAgric).

Looking ahead, the reach and benefits of D4AG will depend on access to mobile phones and connectivity by SHFs in the near future. The future is very bright for Nigeria in terms of mobile phone access, but more needs to be done in terms of connectivity. The cost of accessing data is expected to fall with time, arising from competition among telecom operators and increase in public and private investments in the enabling inland optic fibre infrastructure. This will then stimulate the sluggish mobile money transactions to grow spirally to provide the much needed services to SHFs and other businesses along the various value chains. The private sector must lead the D4AG drive for sustainability in Nigeria. But government needs to step in to provide the fundamentals, which include upgrading small-scale infrastructure and last-mile infrastructures, both of which are ranked below the averages found elsewhere.

Introduction

The role of ICT in Agriculture

Optimal contribution by several actors along agricultural value chain depends largely on information sharing on all activities, from production to consumption decisions. There is a huge role for ICT in bridging communication gaps among farmers, agro-processors, researchers, traders, financial institutions and policymakers. The smallholder farmer must be at the centre of this effort, if food security, productivity and poverty reduction issues facing him are to be resolved. ICT continues to expand in scope and definition. However, due to poverty and infrastructure limitations, even the most basic of ICT facilities, mobile phone, is still largely illusive among most rural dwellers. Yet, to make better and efficient decisions, information is necessary at every stage of the agricultural value chain. Information is essential to cope with price, weather and other uncertainties.

We live in a communication age and communication touches or impacts on virtually every aspect of human endeavour. The Information Communication Technology (ICT) has, for example, brought previous strangers together on mutually beneficial platforms. ICT has reduced the cost of doing business by reducing physical distances to virtual ones. A farmer who owns a mobile phone is now able to reach out to his urban or rural produce buyers or agro-dealers, check his bank account balance and do bank transactions without going outside his rural setting. Different platforms now exist along a given value chain, which, in the aggregate, is expected to positively affect agricultural technology adoption, productivity and income of participants. ICT usage for extension message delivery has become an intervening service between technology adoption and agricultural productivity.

ICT means different things to different people. This study, however, adopts the definition given in Maximo Torero and Joachim von Braun (2006), that ICTs “encompass both equipment and services that facilitate the electronic capture, processing, display, and transmission of information”. The authors elaborated this definition to include “the computing industry (hardware, software, networks, the Internet, and related services); electronic data processing and display (such as photocopiers, cash registers, calculators, and scanners, as well as a myriad of less known machines specifically tailored to production and manufacturing); telecommunications and related services (such as fixed and cellular telephones, facsimile machines, instant messaging, teleconferencing, and so on); and audiovisual equipment and services (including television, radio, video, DVDs, digital cameras, compact disks, MP3 players, and so on).”

In the context of a developing country, such as Nigeria, access of the rural people to ICT is largely defined around the mobile phone. What can be or is done with the mobile phone is further dependent on the type of the phone. Oftentimes, the phones in the rural areas enable only calls or messaging. Even those that enable internet services may be limited by the absence of Internet infrastructure. Access to phones (whatever or not they enable other services) will likely be the main option for communication among the rural people and between them and the rest of the world in times to come. Available literature evidence shows that rural Internet access remains low in the developing world. Yet, the roles of the Internet in fostering access to product markets, input markets, health facilities, and new messages cannot be overemphasized. Thus, to achieve poverty reduction among the rural poor, ICT must be integrated into the overall development agenda.

Access to and effective use of ICT is expected to reduce transactions cost for every participant along an agricultural value chain. While the demand for ICT services may not yet be quantified in developing countries, the challenges to easy access are enormous. These include, in the case of Nigeria, weak infrastructures (telecom, electricity, and roads), low skills to use or maintain the facilities, and the inability to buy mobile phone or airtime or internet data. Until these issues are resolved, a rural-urban divide will persist, probably widened in terms of access to ICT-enabled information. More positively, increased access of the rural sector to ICT in any country that places economic growth prospect on the shoulder of agriculture is more likely to succeed. The annual contribution of the telecom industry to the GDP in Nigeria is estimated to have risen from 7.7% in 2012 to 9.81% in 2018. Increase in rural access to phone and enabled services will create more market for the telecom sector and likely higher contribution to the GDP. Some of the results to keep in focus in this report will include the status of ICT infrastructure in Nigeria, innovation environment for ICT, mobile phone and internet penetration and extent of ICT use in the Nigerian agricultural sector.

Methodology of the Study

Planning meeting for the RC 3 Study

A planning meeting took place in Bonn, October 30-31, 2018, to agree on the scope and methods for the ICT4Agriculture component of the 2019 PARI studies. The draft terms of reference for the study was discussed and reviewed, and the revised version, including the agreed dateline of deliverables, was shared to participating countries. The study was planned to use both deskwork / internet resources and case studies.

Types and Sources of Data

The deskwork aspects of data management are divided into two activities. First is the identification of organizations (Agri-techs) that use ICT to serve agricultural value chains in Nigeria. This was intended as an internet-based exercise. The other deskwork data types relate to the state of infrastructure that support ICT services in Nigeria, obtained from the website of the Nigeria Communication Commission (NCC). The website of the National Bureau of Statistics (NBS) made available household survey data relating to ICT and rural infrastructure; and the websites of the major telecoms (MTN, GLO, Airtel, EMTS) had information on voice call, internet data plans and tariffs.

Sampling for case studies

Following the identification of ICT Agri-techs online, a few of them were shortlisted based on agreed criteria for more detailed case studies (See Appendix A). The case studies were partly to validate the internet claims of the Agri-techs by interviewing them and their users. In order to facilitate the case studies of the Agri-techs and their end-users, a research protocol was shared with RC3 cluster members.

The criteria used to pick the Agri-techs included (see Appendix A): name of service, provider/ operator, start date (and end date, where applicable), functions of the service, target users, value chain stage(s), ICT used for data gathering and analytics, ICTs used for dissemination, status of deployment, cost to users, funding / revenue generation model and contact point

and URL. The shortlist of Agri-techs in Nigeria which met the minimum information criteria based on their websites is as follows: Beat Drone (Nigeria), Kitovu (Nigeria), Paga (Nigeria), Kiakia (Nigeria), Hello Tractor (Nigeria), Farmcrowdy (Nigeria), Releaf (Nigeria), Thriveagric (Nigeria), Mysmartphone, DSI Technologies Limited, E-farms (Nigeria), Quickleap (Nigeria), and Payfarmer (Nigeria). The initial shorter list of Agri-techs which were approached for a case study interview (for themselves and their farmers) were Kitovu (Nigeria), Farmcrowdy (Nigeria), ThriveAgric (Nigeria), E-farms (Nigeria) and Payfarmer (Nigeria). A sample of 20-25 farmers was recommended per Agri-tech with the aim to using 3 Agri-techs per country. Eventually, only ThriveAgric and E-farms granted access to their farmers; FarmCrowdy and Kitovu only granted organizational interviews. Data were analysed using frequency tables, percentages and paired t-tests.

Results and Discussion

State of Infrastructure Deployment for ICT

Based on the information available, the status of infrastructure for ICT in Nigeria has been organized in this report into installed capacity for voice calls, optic fibre installations, base transmission stations (BTS), microwave installations and access to electricity.

Installed capacity for voice subscriptions:

Table 1: shows the installed capacity for voice subscription for 2012-2014. The installed capacities for voice calls appeared to have grown between 2012 and 2014 for the GSM operators. No further information on installed capacities was available after 2014 (see NCC, 2019).

Table 1: Planned number of voice subscribers to be reached (installed capacities), 2012-2014

Network	Service	Installed capacity		
		2012	2013	2014
MTN	GSM	72,000,000	80,000,000	80,000,000
GLO	GSM	37,150,107	39,396,740	39,396,740
AIRTEL	GSM	41,790,000	58,000,000	58,000,000
EMTS	GSM	30,000,000	40,000,000	40,000,000
VISAFONE	CDMA	6,700,000	6,700,000	
STARCOMMS	CDMA	6,720,000	5,100,000	
Total		194,360,107	229,196,740	217,396,740

Source: NCC (2014); NBS (2015)

The total subscription among the networks grew from 194,360,107 in 2012 to 229,196,740 in 2013, but dropped to 217,396,740 in 2014. As will be discussed later, the drop in the CDMA voice subscription capacity was due to the acquisition of CDMA telecoms by the bigger operators, which subsequently rendered them idle.

Base transmission stations (BTS)

Table 2 shows the number of BTS across the country for the 2012-2014 period. This infrastructure class obviously grew during the data period among the main GSM operators (MTN, GLO and Airtel). The total BTS installed by the networks grew from 25,723 in 2012, to 30,869 in 2013, and to 32,885 in 2014. The CDMA operators installed much smaller numbers of BTS, compared to the GSM operators. In any case, the former were eventually acquired in 2014. As an update to Table 2, the total number of base stations nationally were 33,858 in 2015 and 31,292 in 2016, respectively (NCC, 2016).

Table 2: Number of base transmission stations (BTS) in Nigeria, 2012-2014

Network	service	No. of Base Transmission stations		
		2012	2013	2014
MTN	GSM	8,467	11,551	12,557
GLO	GSM	5,836	6,305	6,677
AIRTEL	GSM	3,660	5,997	6,186
EMTS	GSM	5,142	4,436	4,756
VISAFONE	CDMA	606	567	695
STARCOMMS	CDMA	743	74	53
Total		25,723	30,869	32,885

Source: NCC (2014); NBS (2015)

Optic fibre Deployment

Several organizations have invested in submarine optic fibre cables that potentially connect Nigeria with the world through Europe. This infrastructure offers huge internet broadband (IBB) capacities. However, internet broadband penetration in Nigeria is still miserably low, specifically less than 10% for the oceanic optical fibre capacities and less than 7% of optic fibre broadband capacity (Agboje et al., 2017). Due to several factors, internet access today in Nigeria is 99% by wireless mobile networks and less than 1% through fixed wireless (Agboje et al., 2017). This situation is illustrated with data in Table3

Table 3: Fixed broadband subscription per 100 subscribers Nigeria

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
0.00	n.r.	0.04	0.05	0.05	0.06	n.r.	0.01	0.01	0.01	0.01	0.06	0.04

Source: ITU World Telecommunication/ICT Indicators database (2017),
website: http://www.itu.int/en/ITU-D/Statistics/Pages/definitions/regions.aspx
n.r. = not reported by source

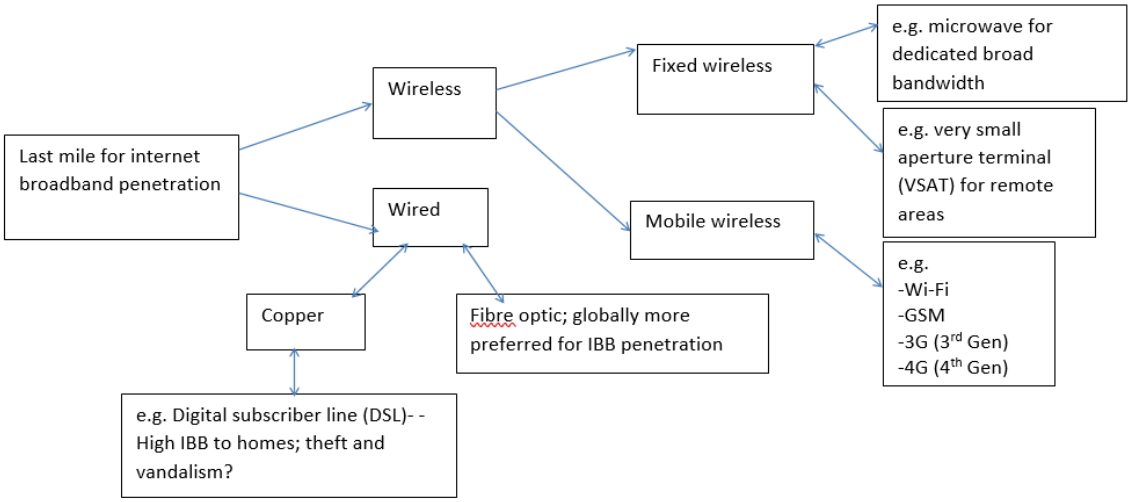
Three levels have been identified for internet broadband deployment in Nigeria using optic fibre networks, namely, the core network, the backbone network and the last-mile networks. The core fibre network connects Nigeria to the rest of the world via Europe. The backbone network connects the states and Internet Service Providers (ISPs). The access or last-mile networks connect the base transmission stations (BTS) to end-users, including homes (see Figure 1). Not much progress has been made with the last-mile infrastructure, compared to the other two levels, which has made broadband internet access costly, relative

to other African countries. The core network connections in Nigeria are championed by five optic fibre operators (Agboje et al, 2017).

Subject to data availability, indicators of coverage are computed in terms of the percent of the population with access to 3G or higher mobile signal, number of subscribers / base station, investment /subscribers and extent of fibre rollout (Gillwald et al., 2018). Mobile wireless internet access is limited by coverage, number of users per site and scarcity of devices with 4G capability. These limitations are overcome where there is access to fixed wired/wireless facilities. The 4G wireless is still limited to cities, such as Lagos, Abuja and Port Harcourt. There are 5 submarine fibre optic cable networks connecting Nigeria to the rest of the world with a promised IBB capacity of over 27Tbps (Agboje et al., 2017). This capability is, however, not available to the ordinary end-user. Rather, the facilities available are focused on meeting the telecom's own challenges and/or organizations that can afford the high cost of IBB connectivity.

Challenges of Optic Fibre Deployment in Nigeria

Optic fibre deployment in Nigeria faces some important challenges. First, government's infrastructural implementation often threatens private telecom's installations, e.g. destruction of underground cables during road construction by government. Second, every ISP lay optic fibre around the country, with no attempt at infrastructure sharing. The main problem in this regard is government's issuance of individual licences. Three, telecoms frequently face security challenges in relation to theft and vandalism of laid (especially metallic) cables. Fourth, there is low government investment in optic fibre infrastructure. This has slowed the penetration of IBB for end-users.



Source: Sketched based on the narratives by Agboje et al. (2017)

Figure 1: Types of access to Internet Broadband

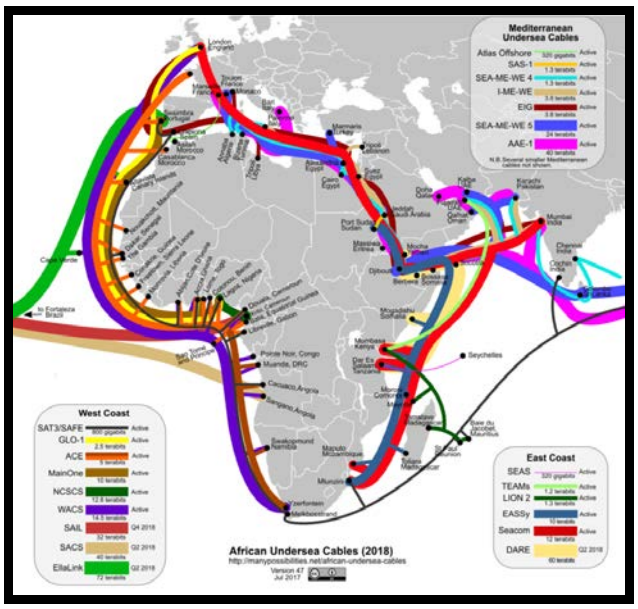
Despite these and other challenges, some achievements have been made as a result of the largely private investments in optic fibre infrastructure in Nigeria. Table 4 shows the deployment of optic fibre by all networks for the available years (2012-2016), expressed in kilometres. Optic fibre is laid inland and in submarine environments. The total optic fibre cable deployed in 2016 was 57,234km, consisting 47,347km (inland) and 9, 887km submarine. The intercontinental picture of the optic fibre infrastructure is illustrated in Figures 2 and 3. The national optic fibre coverage is illustrated for the two leading networks in Figures 4 and 5.

Table 4: Deployment of optic fibre by the major networks in Nigeria (2012-2016) in Km

Network	2012		2013		2014		2016	
	Inland	Submarine	Inland	Submarine	Inland	Submarine	Inland	Submarine
MTN	10,450		18,142		19,200		22,45	
GLO	16,244	19,200	18,569	19,200	10,869	9800	13,277	9,800
AIRTEL	4,632	10	6,109	23	6,314	23		
EMTS	137		249		4,300			
MULTILINKS	5,789		5,789		5,789			
VISAFONE	43	0	43	0	43			
MTN-FXD					12,518	6682		
21st CENTURY					5000	1		
ipNX					400	424		
Others							11,616	84
TOTAL	37,295	19,210	48,901	19,223	64,433	16,930		

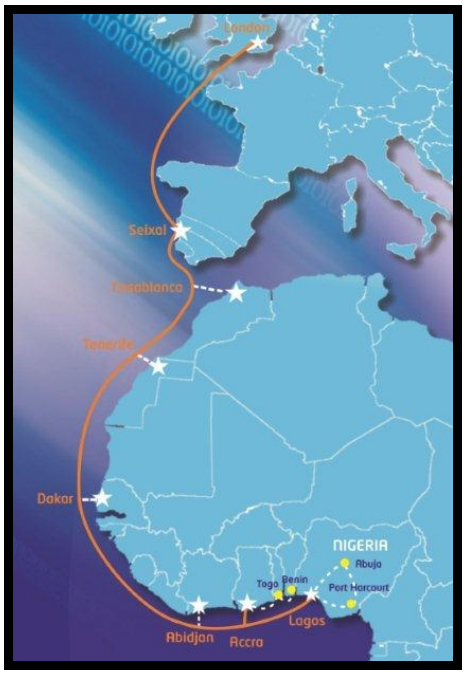
Source: Agboje et al (2017); NCC (2016)

Nigeria's international landed broadband capacity is grossly unavailable for inland usage; indeed, usage is estimated at less than 10% for a country with over 180 million persons. Submarine cables are provided by operators, such as GLO 1 and MTN WACS. A key challenge in the inland unavailability of Nigeria's port bandwidth services is the scarce on-land fibre infrastructure and high access cost at the retail level. In Kenya and Tanzania, government intervened directly in nationwide optic fibre cable infrastructure and allowed the private sector run it to attain conscious cost reduction at the retail end. This policy has enhanced high internet access penetration in both countries, compared to Nigeria. A major investment in optic fibre cable infrastructure along the West Africa coast was undertaken for $300 million by MainOne (Site: https://www.mainone.net/fiber-optic-cable/).



Source: https://manypossibilities.net/african-undersea-cables/

Figure 2: Intercontinental optic fibre layout for Africa

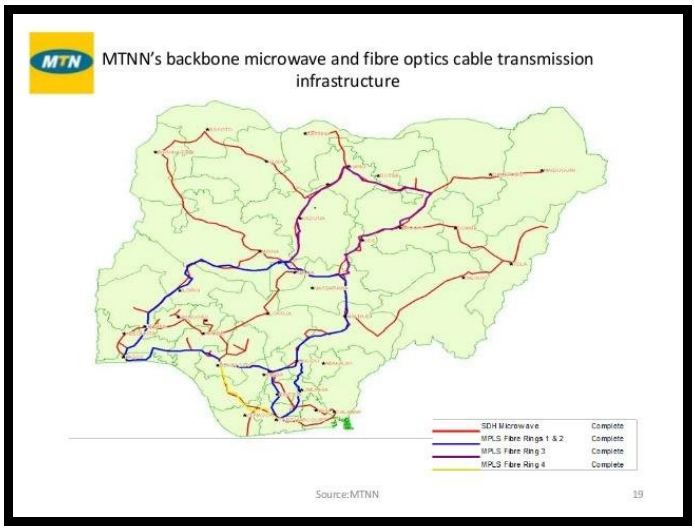


Source: https://www.nigerianmuse.com/20121231040737zg/nm-projects/telecomproject/nigerias-fibre-optic-cables-still-under-utilised-opeke-main-one/

Figure 3: Intercontinental optic fibre layout for Nigeria

Source: Agboje et al. (2017)

Figure 4: Optic fibre and microwave layout by GLO in Nigeria



Source: Agboje et al. (2017)

Figure 5: Optic fibre and microwave by MTN in Nigeria

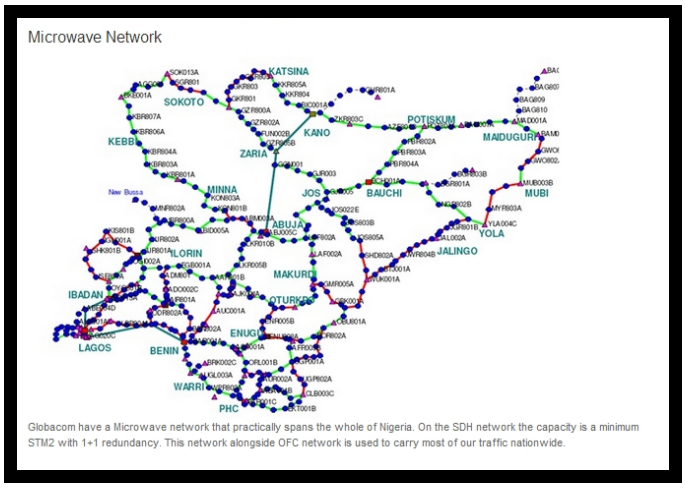
Microwave Radio

Table 5 shows the microwave instalment by the major networks during the 2012-2014 period, also expressed in kilometres. As noticed for the optic fibre, the networks steadily grew their microwave installations from 112,951km in 2012 to 214,625km in 2014. Figure 6 illustrates both optic fibre and microwave infrastructure installations by GLO, while Figure 5 also shows the microwave coverage by MTN.

Table 5: Microwave Radio (Km), 2012-2014

	2012	2013	2014
MTN	11553	11,500	11,553
GLO	65256	75,044	101,800
AIRTEL	11869	13,174	30,283
EMTS	21675	32,780	56,382
VISAFONE	2400	2,000	2,450
MTN-FW		11,553	11,553
21st CENTURY	198	220	180
ipNX		424	424
TOTAL	112,951	146,695	214,625

Source: NCC (2014)



Source: https://www.nigerianmuse.com/20121231040737zg/nm-projects/telecomproject/nigerias-fibre-optic-cables-still-under-utilised-opeke-main-one/

Figure 6: Microwave investment by GLO (Km)

Electricity infrastructure and Access

Table 6 shows the various power options among respondents during the 2010 household survey by NBS. This study, however, focused on the rural, urban and national data. The publicly run electricity company (NEPA/PHCN) was the main source of power for 83.2% of the urban respondents, 82% of the rural respondents and 82% of the full sample. Rural electrification, which is still under the oversight of PHCN, came in distant second as the next power source option for 2.7% of the urban dwellers, 7.5% of the rural dwellers and 5.5% of the full sample.

Table 6: Percentage Distribution of Household by Source of Electricity Supply, 2010

Sector	PHCN (NEPA) Only	Rural		PHCN	Rural Electricity/ Generator	
URBAN	83.2	2.7	0.8	11.3	2.1	0.0
RURAL	81.5	7.5	2.0	6.2	2.6	0.1
National	**82.2**	**5.5**	**1.5**	**8.4**	**2.4**	**0.1**

Source: National Bureau of Statistics (2012)

According to the survey by Gillwald et al. (2018), 66% of Nigerian households were connected to the main electricity grid; 33.1% did not have an electricity connection at all; 11.4% depended on generators, while less than 1% had access to solar power (Table 7). The data in Tables 6 and 7 agree that Nigerians depended mainly on publicly run and poorly accessed power grid and supplements this with generators.

Table 7: Electricity connections to households, Nigeria

Electricity options	%
No electricity	33.3%
Main electricity grid	65.9%
Generator	11.4%
Solar	0.04%

Source: Gillwald et al (2018)

Mobile Network Coverage

Mobile network coverage in Nigeria is presented in one of two ways, namely, using the national network maps and/or the geographical spread of subscriptions. Figures 4 and 5 already showed the operational map of GLO and MTN networks in Nigeria. The maps did not show the extent of rural penetration; but they demonstrated presence of the two networks in all the capital cities, plus the Federal Capital Territory (FCT).

Voice and Internet Subscription

A further demonstration of network spread is GSM use for voice call and internet. Table 8 demonstrates the extent to which both voice and internet subscriptions had spread across all the states in Nigeria by December 2017. The emphasis here was not on the total subscription, which has been described elsewhere in the report, but on the nationwide spread of subscribers.

Table 8: Total number of active voice and internet subscribers, by GSM and states, Nigeria, December 2017

Total active voice (GSM)				Total active Internet (GSM)			
STATE	Total GSM	STATE	Total GSM	STATE	Total GSM	STATE	Total GSM
ABIA	2,945,029	KADUNA	6,629,680	ABIA	1,959,898	KADUNA	4,491,573
ADAMAWA	2,647,130	KANO	7,376,773	ADAMAWA	1,694,048	KANO	4,634,556
AKWA IBOM	2,804,475	KASTINA	3,401,067	AKWA IBOM	1,782,530	KASTINA	2,189,752
ANAMBRA	4,043,011	KEBBI	2,031,939	ANAMBRA	2,708,005	KEBBI	1,288,708
BAUCHI	2,740,255	KOGI	2,927,247	BAUCHI	1,799,926	KOGI	2,071,923
BAYELSA	954,288	KWARA	3,214,402	BAYELSA	681,933	KWARA	2,181,043
BENUE	3,472,102	LAGOS	19,118,767	BENUE	2,351,154	LAGOS	13,501,817
BORNO	2,693,586	NASSARAWA	3,332,735	BORNO	1,681,512	NASSARAWA	2,265,898
CROSS RIVER	2,060,704	NIGER	5,262,503	CROSS RIVER	1,363,857	NIGER	3,525,712

DELTA	4,687,811	OGUN	9,171,533	DELTA	3,248,424	OGUN	6,433,841
EBONYI	1,214,184	ONDO	3,341,775	EBONYI	748,251	ONDO	2,348,915
EDO	4,630,084	OSUN	3,499,404	EDO	3,222,762	OSUN	2,410,920
EKITI	1,274,909	OYO	7,742,913	EKITI	883,504	OYO	5,361,124
ENUGU	2,950,704	PLATEAU	3,089,003	ENUGU	1,929,085	PLATEAU	2,107,292
FCT	5,909,633	RIVERS	5,444,070	FCT	4,191,035	RIVERS	3,712,466
GOMBE	1,786,964	SOKOTO	2,060,510	GOMBE	1,165,182	SOKOTO	1,317,215
IMO	3,044,332	TARABA	2,051,673	IMO	1,968,965	TARABA	1,282,180
JIGAWA	1,725,784	YOBE	1,631,404	JIGAWA	1,042,787	YOBE	961,031
		ZAMFARA	1,728,294			ZAMFARA	1,022,080

Source: NCC (2018)

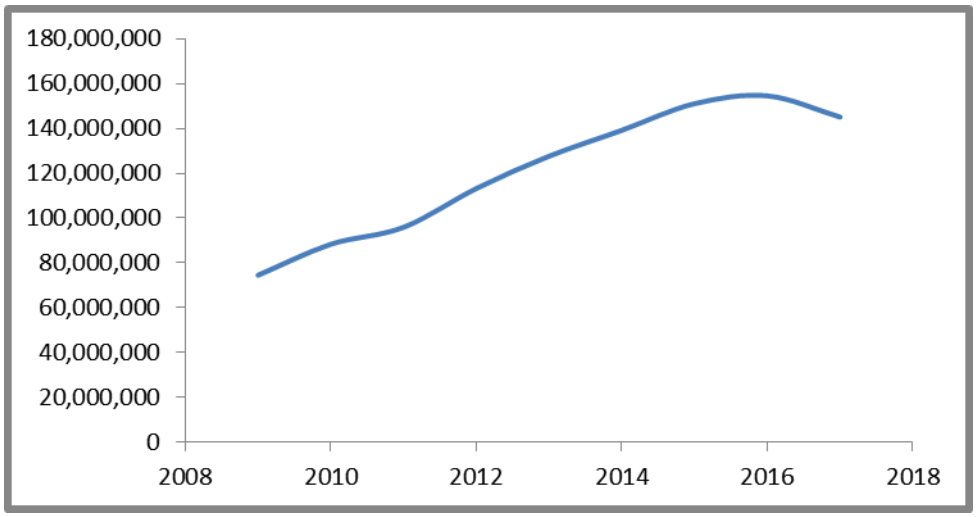
Mobile Subscription

Mobile subscription, presented in terms of the number of subscribers, is described in this report using the available annual and monthly data for Nigeria and the annual data for the three countries in the study cluster (Nigeria, Ghana and Kenya). The available annual data is for voice subscription. Table 9 shows that voice subscription grew steadily from 74,518,264 in 2009 to 154,529,780 in 2016, but dropped by 6.1% to 145,065,953 in 2017. Figure 7 illustrates this trend further.

Table 9: Total annual voice subscription, 2009-2017, Nigeria

Year	Total active voice subscription
2009	74,518,264
2010	88,348,026
2011	95,886,714
2012	113,195,951
2013	127,606,629
2014	139,143,610
2015	151,017,244
2016	154,529,780
2017	145,065,953

Source: NCC (2018)



Source: Calculated from Table 9

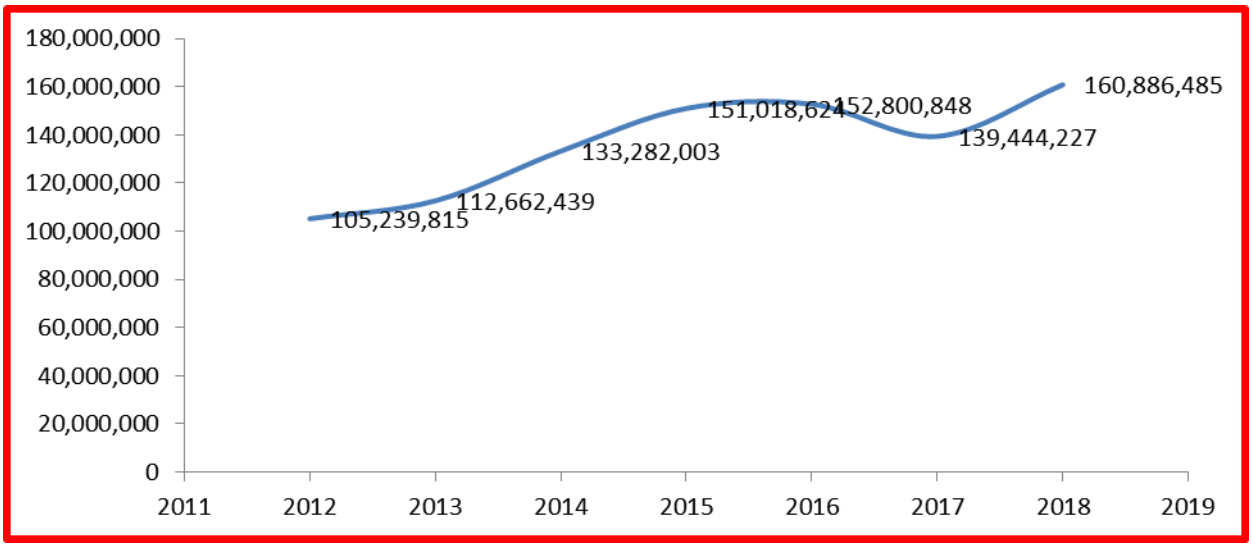
Figure 7: Annual total active voice subscription, Nigeria 2009 – 2017

Table10 shows the monthly voice subscription from May 2012 to August 2018. Figure 8 shows the plot for a representative month, namely, August, from 2012 to 2018. Except for the unexplained drop in 2017, the total voice subscriptions in the month of August annually grew from 105,239,815 in 2012 to 160,886,485 in 2018. The NCC, the data source, did not publish accompanying explanation for the 2017 drop in the total voice subscription.

Table 10: Monthly total subscription to voice call, Nigeria, 2012-2018

	2018	2017	2016	2015	2014	2013	2012
Dec	n.r.	145,059,514	154,529,780	151,017,244	139,143,610	127,606,629	113,195,951
Nov	n.r.	142,320,120	153,949,450	152,123,172	136,637,853	123,740,224	110,348,131
Oct	n.r.	140,766,653	153,514,107	152,003,124	135,618,994	121,888,014	109,499,882
Sep	n.r.	139,905,213	153,299,535	150,660,631	134,507,196	121,271,218	107,367,095
Aug	160,886,485	139,444,227	152,800,848	151,018,624	133,282,003	112,662,439	105,239,815
Jul	161,792,917	139,144,705	150,262,066	150,741,005	132,186,840	114,760,406	103,425,458
Jun	162,763,480	143,064,490	149,818,906	148,775,410	132,780,703	120,362,218	102,369,999
May	162,522,772	145,350,702	148,848,158	146,561,744	131,182,520	120,748,754	101,814,533
Apr	160,524,590	149,249,510	147,568,310	145,476,326	129,391,392	119,356,665	n.r.
Mar	149,293,870	152,467,198	148,745,464	143,934,208	127,097,196	117,281,669	n.r.
Feb	148,398,425	154,120,484	148,620,359	142,589,775	128,264,572	116,601,637	n.r.
Jan	147,296,344	155,113,547	151,357,769	140,822,483	127,960,580	114,492,384	n.r.

Source: NCC (2018); n.r. = not reported at the time of access



Source: Calculated from Table 10

Fig 8: Total Number of Voice Subscriptions for the Month of August, 2012-2018

Table 11 shows a comparison of voice subscriptions among Nigeria, Ghana and Kenya from 2000 to 2017. Teledensity data are used as proxy because they are more comparable across countries per 100 inhabitants than the absolute number of subscribers. As more clearly illustrated in Figure 9, Ghana had much higher mobile subscription per 100 inhabitants than Nigeria and Kenya during most of the data period. However, the teledensity rate maintained an upward trend for all the three countries during the data period. In the case of Nigeria, teledensity dropped from 83.25 in 2015 to 82.98 in 2016 and 75.92 in 2017 per 100 inhabitants. It is not clear why the steady growth changed after 2015, but Proshare (2017) suggested that this may be connected with the increased market concentration, which leaves little incentive for expansion. For example, the major networks acquired all the CDMA telecoms by 2014, but discontinued the services previously rendered by the smaller companies after acquisition.

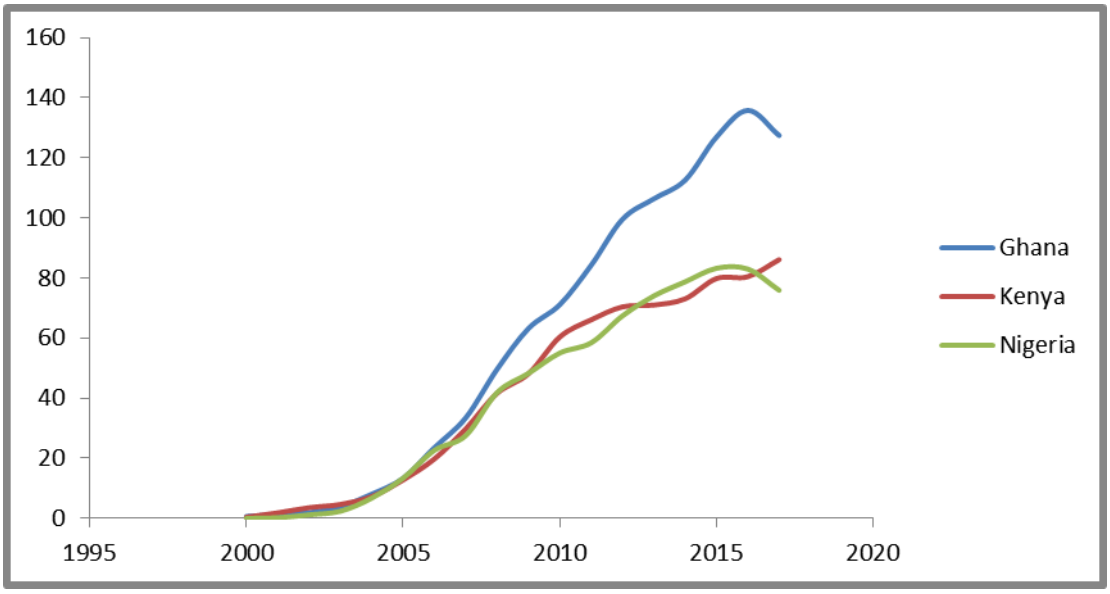
Table 11: Mobile cellular telephone subscriptions per 100 inhabitants (teledensity), 2000-2017

Year	Ghana	Kenya	Nigeria
2000	0.69	0.41	0.02
2001	1.26	1.86	0.21
2002	1.94	3.57	1.22
2003	3.89	4.66	2.39
2004	8.08	7.26	6.76
2005	13.34	12.79	13.38
2006	23.55	19.81	22.66
2007	33.50	29.80	27.59

Year	Ghana	Kenya	Nigeria
2008	49.66	41.65	41.90
2009	63.21	48.13	48.26
2010	71.14	60.38	55.05
2011	84.25	66.09	58.43
2012	99.55	70.41	67.41
2013	106.38	71.01	74.05
2014	112.60	73.08	78.75
2015	126.92	79.85	83.25
2016	135.80	80.44	82.98
2017	127.46	86.15	75.92

Source: ITU World Telecommunication (2017)

Figure 9: Mobile cellular telephone subscriptions per 100 inhabitants (teledensity), 2000-2017



Source: Calculated from Table 11

Market Share

Share of active lines among technologies

The lower panel of Table 12 shows the percentage distribution of the active lines among the major technologies. Consistently, the mobile GSM was the dominant technology among the active lines during the data period (2010-2016).

Short Message Services (SMS)

Table 13 shows the flow of incoming and outgoing SMS among the networks in 2014 and 2016. In 2014, the largest SMS transaction was with MTN (38%), followed by Airtel (27%), GLO (18%) and EMTS (16%). By 2016, however, the share structure changed dramatically in favour of MTN (67%). The data source did not provide any explanation for this structural change; but this study linked it to the acquisition of the smaller networks by the bigger ones (especially MTN) in 2014, suggesting increased market power.

Table12: Share of active lines among technologies, Nigeria, 2010-2016 (%)

		2016	2015	2014	2013	2012	2011	2010
Active Lines	Mobile (GSM)	154,124,602	148,681,362	136,772,475	124,841,315	109,829,223	90,566,238	81,195,684
	Mobile (CDMA)	217,566	2,148,727	2,187,845	2,404,777	2,948,562	4,601,070	6,102,105
	Fixed Wired/Wireless	154,513	187,155	183,290	360,537	418,166	719,406	1,050,237
	Total	154,529,780	151,017,244	139,143,610	127,606,629	113,195,951	95,886,714	88,348,026
Share (%)	Mobile (GSM)	99.7	98.5	98.3	97.8	97.0	94.5	91.9
	Mobile (CDMA)	0.1	1.4	1.6	1.9	2.6	4.8	6.9
	Fixed Wired/Wireless	0.1	0.1	0.1	0.3	0.4	0.8	1.2
	Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: NCC (2016)

Table 13: Share of incoming and outgoing SMS among networks, 2014 and 2016 (%)

	2014				2016			
	Sent	Received	total	Share (%)	Sent	Received	total	Share (%)
MTN	739,000,000	1,125,000,000	1,864,000,000	38.4	2,945,743,960	3,090,010,066	6,035,754,026	67.4
GLO	515,704,665	348,141,363	863,846,028	17.8	14,014,234	23,549,210	37,563,444	0.4
AIRTEL	577,594,753	738,917,112	1,316,511,865	27.1	721,323,313	809,824,468	1,531,147,781	17.1
EMTS	430,417,825	348,559,265	778,977,090	16.0	689,848,385	652,143,103	1,341,991,488	15.0
MULTILINKS	24,965	42,832	67,797	0.0			0	0.0
SMILE			0	0.0	2,399,628	52,346	2,451,974	0.0
VISAFONE	17,430,331	17,236,197	34,666,528	0.7			0	0.0
MTEL			0	0.0	1,103,960	204,702	1,308,662	0.0
TOTAL	2,280,172,539	2,577,896,769	4,858,069,308	100.0	4,374,433,480	4,575,783,895	8,950,217,375	100.0

Source: NCC (2016)

Market Share of Voice Subscriptions:

Table 14 shows the share of total subscription (voice call) in selected months between 2014 and 2018. For the periods available, the shares of the subscriber market were distributed on the average of 40% (MTN), 24% for GLO and AIRTEL, and 13% for EMTS, while others had 5%. The market leaders in terms of total subscription were MTN, GLO and Airtel, with MTN

standing ahead like previously observed for the SMS market. The data source did not render any explanation for this observation. But it is very likely that voice subscription and SMS market shares are measured with different benchmarks, so they may not directly compare, except to show the same broad picture. In any case, the tariff structures for SMS and voice calls might have played a major role in the distribution of market shares for SMS and voice subscriptions. Tariff structures are addressed later in the report.

Table 14: Market shares of total subscriptions by operators, selected periods from 2014 to 2018 (%)

	Aug 2018		Dec 2017		Dec 2014		
Network	**subscription**	**Share (%)**	**subscription**	**Share (%)**	**subscription**	**Share (%)**	**Ave.**
MTN	64,106,166	40.00	52,281,686	36	59,893,093	44	40
GLO	40,495,418	25.00	38,169,780	26.3	28,219,089	21	24
AIRTEL	40,508,087	25.00	37,233,819	25.7	27,556,544	20	24
EMTS			16,955,392	11.7	21,103,749	15	13
Others	15,411,322	10.00	425,276	0.3	0	0	5
total	160,520,993	100.00	145,065,953	100	136,772,475	100	100

Source: NCC (2018)

Access to Mobile Phone

A state by state analysis of access to mobile phone was undertaken by NBS based on a 2010 household survey. But this report focused on the urban, rural and national aggregates of the available data (Table 15). The results show that 52.9% of the sample owned mobile phones in the urban areas, while 24.4% owned mobile phones in the rural areas. Nationally, only 30.4% of the sample owned mobile phones in 2010. Adding those with access (only) to those who owned mobile phones, total access improved to 84% in the urban area, 59% in the rural area and 64% nationally in 2010. These 2010 results was benchmarked against the 2016 results and are presented later.

Table 15: Percentage Distribution of Persons by Ownership and Access to Mobile Phone, 2010

Sector	Owned	Access only	total access	No access
Urban	52.9	31.1	84	16.0
Rural	24.4	34.1	58.5	41.5
National	30.4	33.5	63.9	36.1

Source: National Bureau of Statistics (2012)

The sources or means of access to mobile phone in the 2010 survey by the NBS are presented in Table 16, with focus on the urban, rural and national data. Among 95% of the urban respondents, access to mobile phone was through family members, friends and neighbours. Among the rural respondents, 92% indicated mobile phone access through family members, friends and neighbours. Nationally, 93% of the respondents indicated that access to mobile phone was through family members, friends and neighbours. Thus, there

seemed to be a strong bond among family members, friends and neighbours that allowed the 'borrowing' of mobile phones for use within the Nigerian society. These 2010 results are benchmarked against the 2016 results and presented next.

Table 16: Percentage Distribution of Persons by Source of Access to Mobile Phone, 2010

Sector	Family member	Friend/Neighbour	Umbrella Centre	Workplace	Business Centre	Other
Urban	63.6	31.5	3.3	0.1	1.6	0.1
Rural	42.2	49.4	5.5	0.1	2.9	0.1
National	48.1	44.4	4.9	0.1	2.5	0.1

Source: National Bureau of Statistics (2012)

The 2015-2016 Living Standards Measurement Study (LSMS) by NBS and World Bank attempted to update aspects of the 2010 results concerning access and means of access to mobile phones in Nigeria. The regional results are presented in Table 17; but this study will continue to focus on the rural, urban and national figures. By 2016, 93% of the urban respondents, 86% of the rural respondents and 89% of the full sample had access to mobile phones.

Table 17: Access to mobile phone (% of those 10 years or older), by regions

Region	Access to Mobile phone (%)
North Central	89.7
North East	85.7
North West	82.5
South East	92.4
South-South	88.7
South West	95.5
Urban	92.9
Rural	86.2
Nigeria	88.7

Source: National Bureau of Statistics (2016)

The 2015-2016 LSMS data in Table 18 reveal a bit more than what was shown for the 2010 data (Table 15). In Table 18, access through personal ownership of mobile phones is made explicit and reported as 74% among urban respondents, 48% among rural respondents and

59% for the full (national) sample. If access is added through family members, friends and neighbours, then by 2016, virtually everyone in the sample had access to mobile phones. The figures in the table represent the sources of access to mobile phone/internet among those reported to have access.

Table 18: Means or sources of mobile phone by regions

Source	Owned	Family member	Friend/neighbour	Umbrella centre	Business centre	Other
NC	54.9	38.9	5.8	0.4	0.2	0
NE	39.1	46.3	14.4	0.1	0.1	0.1
NW	40.4	46.4	11.6	0.9	0.6	0
SE	67.6	28	1.5	1.6	1.3	0
SS	73.6	25	1.2	0.1	0.1	0
SW	76.2	22	1.8	0	0	0
Urban	74	24.6	1.2	0.1	0.2	0
Rural	48.3	41	9.4	0.8	0.5	0
National	58.5	34.5	6.2	0.5	0.4	0

Source: National Bureau of Statistics (2016)

Internet Services and Access in Nigeria

Market share of Internet services

Table 19 shows the internet market share among the major networks. By March 2016, there were 92,424,736 Internet subscribers in Nigeria, which was shared among the major networks, at 36.1% (MTN), 28.7% (GLO), 18.6% (Airtel) and 16.5% (EMTS). As it was for voice subscription, the major leaders continued to be MTN, GLO and Airtel, in that order.

Table 19: Market share of Internet services among the major networks, 2016

Network	Subscribers	Share (%)
M TN	33,356,595	36.1
GLO	26,530,420	28.7
AIRTEL	17,155,181	18.6
EM TS	15,242,856	16.5
LTILINKS	142	0.0
ISAFONE	124,768	0.1
IPNX	4,571	0.0
TN FIXED	7,177	0.0
1ST CENT	3,026	0.0
TOTAL	92,424,736	100.0

Source: NCC (2016)

Internet access and means of access

Table 20 shows the distribution of respondents in a 2010 NBS survey on access to the Internet in Nigeria. The survey allowed for responses in terms of access only without owning a means of access and/ or owning the means of access. Perhaps more important is the last column which shows those without internet access. Nationally, 96.4% of the surveyed in 2010 had no internet access. Among the rural respondents, 98.5% had no access and 88.4% of the urban respondents had no internet access in 2010.

Table 20: Percentage Distribution of Persons by Access and Ownership of Internet, 2010

Sector	Owned	Access only	total access	No access
Urban	2	9.6	11.6	88.4
Rural	0.2	1.3	1.5	98.5
National	**0.5**	3.1	3.6	**96.4**

Source: National Bureau of Statistics (2012)

Table 21 shows the distribution of respondents in a 2010 survey by their means or sources of Internet access. Although this kind of survey is occasional rather than annual, the results conveyed good information, nonetheless. Among the urban respondents, the highest sources of access to the Internet were the business centres (62.3%), followed by ownership of the means (23.1%). Among the rural respondents, the business centres maintained the largest means of access. Nationally, 64% of all respondents relied on business centres for Internet access, followed by own sources (14.7%).

Table 21: Percentage Distribution of Persons by Source Access to Internet, 2010

Sector	Owned/ subscribe	Family member/ Friend/Neighbour	Umbrella Centre	Workplace	Business Centre	Other
Urban	16.9	9.1	2	8.7	62.3	1
Rural	10.5	10.2	3	7.9	67.3	1.2
National	14.7	9.5	2.3	8.4	64	1

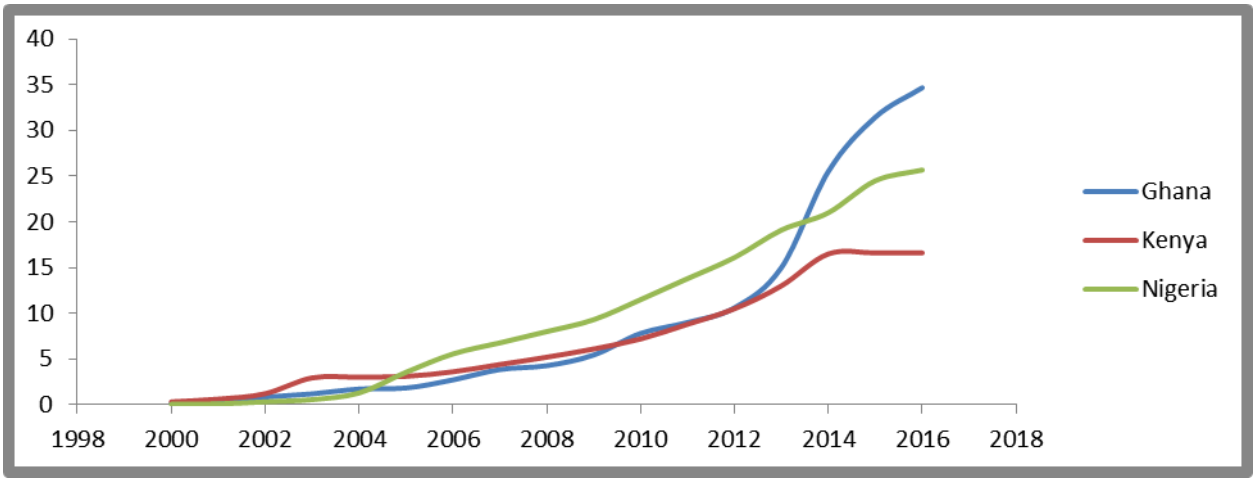
Source: National Bureau of Statistics (2012)

Table 22 and Figure 10 compared Internet usage among the cluster countries in the ICT study. All three countries showed steady and fairly consistent growth in the percentage of persons using internet during the 2000-2016 data period. Figure 10 shows that Nigeria started rather slowly but surpassed Ghana and Kenya after 2005 and till 2013, after which Ghana took a new lead.

Table 22: Percentage of Individuals using the Internet

Year	Ghana	Kenya	Nigeria
2000	0.15	0.32	0.06
2001	0.20	0.62	0.09
2002	0.83	1.21	0.32
2003	1.19	2.94	0.56
2004	1.72	3.02	1.29
2005	1.83	3.10	3.55
2006	2.72	3.60	5.55
2007	3.85	4.40	6.77
2008	4.27	5.20	8.00
2009	5.44	6.10	9.30
2010	7.80	7.20	11.50
2011	9.00	8.80	13.80
2012	10.60	10.50	16.10
2013	15.00	13.00	19.10
2014	25.52	16.50	21.00
2015	31.45	16.60	24.50
2016	34.67	16.60	25.67

Source: ITU World Telecommunication (2017)



Source: Calculated from Table 22

Fig 10: Percentage of Individuals using the Internet (Ghana, Kenya, Nigeria)

The 2015/2016 LSMS agricultural household survey by NBS revised some of the 2010 internet access and means of access data presented earlier (Table 20). In comparison, the data in Tables 20 and 23 show that urban internet access moved up to 29% from 11.6%; rural internet access increased from 1.5% to 9.8% and the national internet access increased from 3.6% (2010) to 17.4% (2016).

Table 23: Access to mobile phone and internet (% of those 10 years or older), by regions

Region	Access to internet (%)
North Central	18.2
North East	10.2
North West	7.1
South East	20.1
South-South	28.4
South West	23.1
Urban	29.0
Rural	9.8
Nigeria	17.4

Source: National Bureau of Statistics (2016)

The data in Table 24 represent the source of access to the Internet among those with access. An important structural shift in the means of internet access can be seen comparing Tables 21 (2010) and 24 (2016). The percentage of those who owned/ subscribed to Internet among urban respondents increased from 16.9% (2010) to 75.5% (2016); rural subscription increased from 10.5% to 77.5%, while nationally, subscription increased from 14.7% (2010) to 76.2%. On the other hand, urban respondents who sought internet access from business

centres dropped from 62.3% in 2010 to just 10.8%; the rural users of business centres dropped from 67.3% in 2010 to 9.9% in 2016. Nationally, business centre users dropped from 64% in 2010 to 10.5% in 2016.

Table 24: Means or sources of mobile phone and Internet access, by regions

Source	North Central	North East	North West	South East	South South	South West	Urban	Rural	National
Owned/subscription	72.2	66.5	69.8	74.3	80.5	80.3	75.5	77.5	76.2
Family	14.3	14.3	11.7	6.2	10.9	11.6	11.6	10.7	11.3
Umbrella centre	0.	3.2	0.7	1.5	0.1	0.0	0.6	0.5	0.6
Workplace	2.	0.4	1.4	0.7	0.3	1.1	1.2	0.8	1.1
Business centre	9.	13.8	16.4	17.3	8.1	6.5	10.8	9.9	10.5
Other	0.	1.8	0.0	0.0	0.1	0.5	0.3	0.7	0.4

Source: National Bureau of Statistics (2016)

The purpose of using internet was examined by the 2015/2016 LSMS survey of NBS, and the results are presented in Table 25. The top use of the Internet was to send/receive emails among the urban (46.3%), rural (45.0%) and all (45.8%) users. The use of Internet for banking services was a dismal result among urban (0.4%), rural (0.5%) and all (0.4%) users.

Table 25: Purpose of Use of Internet (% of those with Internet Access)

Purpose	North Central	North East	North West	South East	South South	South West	Urban	Rural	National
Send/receive email	41.6	27.6	33.2	59.0	43.0	52.7	46.3	45.0	45.8
Education/learning activities	12.5	20.4	32.7	9.2	17.8	21.5	20.8	13.6	18.4
Post information or instant message	17.3	25.4	11.1	8.3	22.2	11.0	13.7	18.8	15.4
Read/download newspapers, magazines	11.5	16.1	11.0	8.8	7.3	4.6	8.0	9.3	8.4
Get information about government organization	2.6	2.6	6.4	3.9	3.3	0.8	2.9	2.7	2.8
Download movies, images, or music	13.8	6.3	3.5	9.8	5.5	8.2	7.2	9.7	8.0
To access/monitor banking services	0.7	1.5	2.1	0.6	0.0	0.7	0.8	0.5	0.7
Other	0.0	0.0	0.0	0.5	1.0	0.4	0.4	0.	0.4

Source: National Bureau of Statistics (2016)

Cost of Voice call, SMS and Internet Subscription

Voice and SMS tariff plans of the major networks

Tariffs are approved by the NCC for voice and SMS services, and networks compete within the rates approved for them. For Globacom (GLO for short), voice call tariff varied from 11 to 30 kobo/sec, depending on the bundle plan and SMS was charged at N4/page (a page is 160 characters) for local services and N15/page for international services (NCC, 2019). For MTN, voice call tariff varied from 11 to 40 kobo/sec, depending on the bundle plan. SMS was charged at N4/page for local services and N15/page for international services (NCC, 2019). And for Airtel, voice call tariff varied from 11 to 40 kobo/sec, and SMS was charged at N4/160 characters for local services and N15/160 characters for international services (NCC, 2019). Clearly, the networks were bounded by common tariff regulations, but they came up with different bundle plans for maximum advantage (e.g. NCC, 2019b, NCC, 2019c).

Internet data plans of major networks

The Internet data plans of the three leading networks (MTN, GLO and Airtel) are shown in Tables 26-28. Without going into descriptive details for each network, a pattern that cuts across in the tables is that competition over the years has forced data tariffs to be comparable across networks. For example, the tariffs for the monthly plans for 1GB, 1.5GB and 2GB were uniformly the same across the 3 major networks, even though regulation allows higher tariffs. Going into other plans revealed fairly comparable tariffs. Beyond comparability, however, it was not clear how many subscribers were coping with the tariffs associated with the various plans. Although not directly investigated, the low Internet penetration in Nigeria was likely jointly explained by both the state of infrastructure and the prevailing data tariffs.

Table 26: GLO Data Plan Details

Data Volume	Data Volume with Bonus	Price (N)	Validity
10MB	12.5MB	N25	1 Day
22MB	27.5MB	N50	1 Day
80MB	100MB	N100	1 Day
210MB	262MB	N200	5 Days
800MB	1GB	N500	14 Days
1.6GB	2GB	N1,000	30 Days
3.65GB	4.5GB	N2000	30 Days
5.75GB	7.2GB	N2,500	30 Days
7GB	8.75GB	N3,000	30 Days
10GB	12.5GB	N4,000	30 Days
12.5GB	15.6GB	N5,000	30 Days
20GB	25GB	N8,000	30 Days
26GB	32.5GB	N10,000	30 Days
42GB	52.5GB	N15,000	30 Days
50GB	62.5GB	N18,000	30 Days
63GB	78.75GB	N20,000	30 Days

Source: https://www.gloworld.com/ng/personal/data/data-plans/ (June 21, 2019)

Table 27: Airtel Data Plans

Price	Data Allowance	Validity
N50	20MB	1 Day
N100	75MB	1 Day
N200	200MB	3 Days
N300	350MB	7 Days
N500	750MB	14 Days
N9,999**	30GB	30
N19,999**	80GB	30
N1,000	1.5GB	30 Days
N1,500	2.5GB + ***1GB Night	30 Days
N2,000	3.5GB	30 Days
N2,500	4.5GB + ***1GB Night	30 Days
N3,000	5.5GB + ***1GB Night	30 Days
N4,000	7.5GB + ***2GB Night	30 Days

Source: https://www.airtel.com.ng/data/data_offers/data_plans (June 21, 2019)
**Note that these plans can be used Only on Airtel 4G Network; ***Night Data is usable 1AM - 7AM Daily

Table 28: MTN Data Plans

Price (Naira)	Data Allowance	Validity
₦50	20MB	1 day
₦100	50 MB+25 MB**	1 day
₦200	150MB + 75MB**	1 day
₦500	500MB + 250MB**	Weekly
₦100	50MB	1 day
₦1000	1GB + 500MB**	30 days
₦1200	1.5GB	30 days
₦2000	2.5GB + 1GB**	30 days
₦3500	5GB	30 days
₦5,000	10GB	30 days
₦10,000	22GB	30 days
₦20,000	50GB	60 days
₦50,000	85GB	90 days

Source: https://mtnonline.com/data-plan (June 21, 2019) ** Bonus, mostly usable 1.00am-7.00am only

Innovation Environment for ICT in Nigeria

This section is presented under subsections on policy and regulatory framework, property rights, innovation hubs, venture capital and start-up facilities, as relevant to Nigeria.

Policy and Regulatory Framework

The use of ICT in Nigeria occurs within a fairly robust regulatory and policy framework. Some of these are described in the next few subsections.

The Nigerian Communications Act 2003

Two Decrees in 1992, the National Broadcasting Commission (NBC) Decree 38 and the Nigerian Communications Commission (NCC) Decree 75 changed the ICT environment permanently; they both began the opening of the broadcasting and telecom markets. The liberalization was strengthened by the 1998/99 Amendments to both Decrees. The Nigerian Communications Act 19 of 2003 repealed and replaced the NCC Decree of 1992. The 2003 NCC Act created a fully autonomous body with exclusive powers to licence and regulate both private and government-owned telecom operators. The National Information Technology Development Agency (NITDA) Act was passed in 2007 with the aim of promoting IT penetration and overseeing public sector IT projects. Several proposals to merge NBC, NCC and NITDA have been tabled, but implementation had suffered setbacks. The overlap of the functions of the 3 agencies is not in doubt.

The Nigerian Communications Commission

The Federal Ministry of Communications (FMC) formulates policy on communications. The NCC implements policies on telecommunications. The NCC Act lists its functions to include administration of the national numbering plan, facilitating private sector participation and investment in the telecom sector, licensing of telecom operators, assignment of frequencies to licensed operators, promoting and enforcing a fair competitive environment for operators, setting economic regulatory standards, including tariff regulation, promotion of universal access to telecom services, establishment and enforcement of technical operational standards for all operators, including the imposition of penalties for violations, and ensuring the protection of public interest (NCC, 2013). Some of the specifics of the regulatory framework and their implications for ICT development are outlined:

Nigeria's Vision 20:2020 Document

Nigeria's Vision 20:2020 is a document that gives strategic importance to ICT in the bid to develop the country's education, finance, farming, trade, manufacturing, services, oil and gas and the public sector (Gillwald et al., 2018). The ICT segment of Vision 20:2020 recognizes the need to develop local skills to maximize the benefits of ICT, and ensure affordable ICT infrastructure and services, among other requirements for rapid ICT diffusion.

ICT Sector Policy

The ICT sector is largely liberalized, with roles shared among the policy formulating Federal Ministry of Communications, the national regulatory agency (NCC) and the service providers /licensees within the sector.

Nigeria produced a national ICT policy in 2012 through the Federal Ministry of Communications. The policy document is robust, as it includes such aspects as

infrastructure development, spectrum management, broadband access, capacity development access, national security, software and hardware. Till date, however, there is no agency to oversee the implementation of the national ICT policy (Gillwald et al., 2018). The policy of 2012 was to have another implementing agency, but this is yet to be implemented. Still, a number of public ICT bodies are not even captured in the national ICT policy, namely, the National Space Research and Development Agency (NASRDA), National Frequency Management Council (NFMC) and the Nigerian Internet Registration Association (NIRA).

The National Broadband Plan

There is a National Broadband Plan for the period 2013-2018. The plan aimed to promote IBB deployment, adoption and usage at affordable prices (Federal Ministry of Communications, 2013). The plan also aimed to increase IBB penetration from 6% in 2013 to 30% by 2018, and aspired for various grades of fibre infrastructure, wireless 3G networks and prospects for 4G/LTE as spectrum became available. As noted by Gillwald et al. (2018), the national IBB plan was not operational by 2018. Fortunately, several aspects of the policy were mainstreamed into the activities of NCC. The implementation environment for aspects of the national IBB policy has been reviewed to be unfriendly (Table 29).

Table 29: Selected IBB challenges and implications

s/n	Challenge	Implications for service delivery
1	High cost of the right of way	High cost of leasing transmission infrastructure
2	Multiple regulatory bodies	Multiple taxation by tiers of government
3	Lengthy processing of right of way	Poor, costly and inefficient services to consumers **
4	Agreements at federal level with operators often changed/disregarded at state levels	May lead to incurring of multiple costs and revision of investment budgets **
5	Cable theft and road works lead to damages to fibre installations/infrastructure	Repeating of infrastructure expenses and obstruction of services **
6	Erratic grid electricity supply	Poor, costly and inefficient services to consumers **
7	Fragile backbone infrastructure	Poor, costly and inefficient services to consumers **
8	Limited investment in IBB industry	Poor, costly and inefficient services to consumers **

Source: Onkoji (2016); **suggestions by this study

Telecommunications licenses and spectrum allocation

A **license** must be issued at some payable fee for a telecom company to operate in Nigeria. Two types of operating licences are issued: individual licence (issued to a person) and class licence (issued to any or all persons to conduct specified activity). All licences are subject to terms and conditions in the Act. The NCC reserves the right to revoke or suspend a licence. **Spectrum** is the medium for delivering voice and data services. Three bodies, the NCC, NBC and Federal Ministry of Communications (FMC) share responsibilities for spectrum allocation. NCC allocates to commercial providers and users of telecom equipment and services; NBC allocates to private and public broadcasting organizations, while FMC handles the allocation to government and non-commercial users. There is scarcity of spectrum in Nigeria and this has gravely affected the ability to meet consumer demands for and quality of services.

National Radio frequency Management Policy

There is in existence a National Radio Frequency Management Policy (NRFMP) of 2004, formulated to guide allocation of radio frequency spectrum in Nigeria. The NRFMP was intended to be implemented by the National Frequency Management Council (NFMC). However, the NFMC never really took off in terms of establishment; so, the NCC has implemented most of the NRFMP guidelines, which include radio frequency allocation fees, eligibility, renewals, sanctions and allocation procedures (Odufuwa, 2010). The NCC assigns frequencies using open or selective auctions, tenders and fixed prices (APC, 2010). Table 30 shows the available frequencies with NCC.

Table 30: NCC's frequency assignments (2001 till date)

Frequency	450MHz	800MHz	900MHz	1800MHz	2100MHz	2.1GHz
Purpose	Unified access	LTE	GSM	GSM	3G	Wireless
Frequency	2.2GHz	2.3GHz	3.5GHz	5.4GHz	10.5GHz	26GHz
Purpose	Wireless	Wireless	Wireless	Wireless	Wireless	Wireless

Source: Gillwald et al,2018

The auction procedure for spectrum allocation has been problematic. Lots of spectrum in the 2.6GHz band has been priced out of the reach of most operators, leading to failed bidding. According to Song (2017), MTN was the only operator able to pay the reserved price of USD16 million/lot, resulting in some spectrum being left unsold. Thus, MTN Nigeria was the sole winner of the 2016 auction. The result is that consumers of other smaller operators suffer poor connection and data services.

Competition among operators

Available reviews suggest that the most prevailing mobile technologies among Nigerian operators, namely 2G and EDGE, are old (Gillwald et al., 2018). The 3G option is catching up fast among mobile network operators, and 4G is available mainly in big cities. In essence, voice consumers get less service than they paid for. The telecom operators engage in significant competitions among themselves, mostly to the detriment of improved services. In its quest for dominance, MTN painstakingly acquired 2.6GHz spectrum as the sole bidder in 2016 and Visafone's 800MHz LTE spectrum in 2015 through the NCC and 700MHz band through the NBC. It was widely suspected that these acquisitions were done mainly for market dominance than for service improvement (Leadership Newspapers, 2016). The

under-utilization or non-usage of modern frequency bands amounted to overall inefficiency in the telecom market.

Helios' acquisition of Multilinks in the sum of USD10 million in 2011 would have increased the fibre infrastructure of the acquirer. However, the asset was believed to have been acquired more for market share improvement, because the infrastructure has not been used since acquired. The competition has meant that the membership of Association of Licensed Telecommunications Operators of Nigeria (ALTON) shrank from 35 to less than 20 prior to 2017 (Gillwald et al., 2018). For fear of the emergence of monopoly in the telecom industry, NCC later restricted MTN from using the LTE spectrum acquired from Visafone. In the context of market liberalization, NCC's move against MTN may be viewed differently as an infringement. The acquisition of Visafone by MTN (2015), Multilinks by Helios (2011), Direct-on-PC by Swift (2013), Monarch and Chromecom by Swift (2015), significantly pointed in the direction of mergers and acquisitions among the operators.

Fair competition will ultimately benefit the end-users of telecom services. And, when competition leads to service price reduction, the revenue base of the operators is expected to improve from expanded demand. Available indices show that Nigeria's telecom market is highly concentrated, with 3 telecom operators sharing more than 80% of the market (NCC, 2018). This market concentration was supposed to encourage collusive tendencies, but the contrary is the case. Price war was very frequent among the top operators (MTN, GLO and Airtel), which ultimately benefitted the consumers. For example, a SIM card was sold at N40,000 at the onset of telecom services in 2001, but in October 2019, it cost just N100 with start-up airtime across all networks. Also, voice call services started on per minute basis with the dominant network (MTN), but this was reversed when a rival network (GLO) introduced per second billing. A key factor in the price war was SIM card portability among the networks. The acquisition of smaller operators in recent years has fostered market concentration (Gillwald et al., 2018). The NCC will need to brace up and prepare to manage these unanticipated market developments for improved industry efficiency and survival.

Tariffs and Mobile Termination Rates (MTRs)

The regulator (NCC) made an unsuccessful attempt in 2016 to set a floor price for data services. Presently, however, tariffs are set competitively by operators and, indeed, the tariffs and rates are largely convergent per unit or bundle of services (Tables 27 to 29). Mobile termination rates (MTRs) or interconnection rates are fees that operators charge for terminating or completing customer calls on each other's network. The rates may be mutually negotiated or regulated. Most often, the regulator intervenes because networks tend to owe each other, ultimately. For example, Gillwald et al. (2018) noted that by 2015, ₦30 billion worth of debt was pending among operators as interconnection or MTR fees.

The ideal competitive situation is for MTRs to decrease and disappear over time. In Nigeria, however, MTRs are high, leading to higher tariffs for customers. Smaller operators find it hard to survive under over-hanging MTRs and consequential customer tariffs. Except the regulator intervenes, there is the tendency for the big operators to refuse call termination for smaller ones, which amounts to anti-competition. A 2013 study showed that MTN and GLO controlled 62% of the market (NCC, 2013b). MTR was forced downward in 2014 and

2015 by the regulator, leading to some retail price reduction. Although MTN temporarily responded with tariff increase, stiff competition from rival operators (Airtel, Glo and 9mobile) forced the network to back off from tariff increase in order to stay competitive.

Infrastructure Sharing

The NCC Act provides for mutually agreed or negotiated sharing of certain infrastructure among operators. The infrastructure that may be shared include right of way, masts, poles, antenna masts and tower structures, ducts, trenches, space in buildings, electric power (public or private source). In practice, however, none of these items was shared. For example, masts, antenna, towers and buildings were visibly seen with distinct network identifications all over the country. The infrastructure items not permitted for sharing include complete network structures, switching centres, radio network controllers, and base stations. Fibre operators lamented variations in the rules guiding right of way from one state government to another. It has been advocated that right of way be upgraded to federal legislation to protect fibre investors.

International Transmission

Following the launch of new undersea cable systems from 2010-2014, there had been massive improvement in the available international bandwidth capacity in Nigeria. The improvement in wholesale international bandwidth, with landing points in Lagos, began in 2010. The major bandwidth wholesalers are MainOne (2010), Glo-1 (2011), WACS (2012) and ACE (2014), with a combined capacity of 9.5tbps (Gillwald et al., 2018) . The international bandwidth comes with lower retail prices and higher speeds, but these benefits are not available for national transmissions, mainly due to limited inland fibre infrastructure. MainOne is noted to be the leading wholesale bandwidth supplier in Nigeria. It is estimated that not more than 4% of the total landed international bandwidth is available inland in Nigeria. Thus, there is massive unused landed bandwidth. The reasons for this are significant. First, the penetration of smartphones is no more than 30% of the population. Thus, there are not enough smartphones to match Long-Term Evolution (LTE) technologies. Two, there is weak corporate demand for bandwidth outside commercial cities, which does not encourage massive private investments in inland distribution of the landed international bandwidths.

National Transmission

The limited state of optic fibre infrastructure is the main challenge against prospect of distributing the excess landed international bandwidth inland. Whatever fibre infrastructure is available for inland transmission is focused on major urban areas and inter-city routes virtually to the neglect of the prospective rural consumers. All the networks put together account for just 57,234km of fibre (NCC, 2016). It has been suggested that a nationwide broadband network is the likely solution to this problem. For fear of risks, however, it is unlikely that private telecoms will undertake such investments. Infrastructure sharing could be a way forward in this regard. Industry sources now believe that it is cheaper to buy bandwidth from outside Nigeria for inland distribution than to take bandwidths from any of the cable systems in Lagos. This again is the limitation imposed by the scarce and costly inland fibre installation. The existing inland fibre installations are known to suffer frequent damages from road construction, terrorism and communal sabotage by aggrieved host communities. Aerial deployment of fibre infrastructure is currently being led by Phase 3 telecom, with over 4,000km success. Phase 3 essentially delivers fibre services along the

national power transmission corridor and is making a huge success of this procedure (Gillwald et al., 2018).

Barriers to Internet Use

This section reviews some of the factors that often impede the use of internet services among households in Nigeria and elsewhere in Africa.

Market concentration

ITU (cited in Gillwald et al., 2018) estimated mobile phone access at 82% and internet penetration at 26% of the population in Nigeria. Undersea cable costs have dropped and have led to reduction in international bandwidth internet access cost. But because there is no corresponding terrestrial internet infrastructure investment, access to fixed wireless internet is still negligible. Gillwald et al. (2018) estimated individual internet usage to be 30% Nigeria, 26% in Ghana and 26% in Kenya. Top among the factors limiting internet access is the disappearance of CDMA service providers from the telecom market. These companies provided fixed wireless connections to individuals, homes and small businesses.

Visafone, the last CDMA operator, was acquired by MTN in 2014 and subsequently rendered redundant after acquisition. Private ISPs are trying to fill the gap, but mainly functional in big cities, such as Abuja, Lagos and Port Harcourt. There are no nationwide ISPs. Several evidence abounds that households get internet connection through their mobile phones, estimated at 75.7% (Gillwald et al., 2018), and negligibly through fixed broadband. There is no national backbone network for promoting high-speed internet connectivity. A good number of subscribers still own non-smartphones, which compel providers to retain their 2/2.5G access networks in order not to lose this class of customers. For those subscribers who own 3/3.5/4G-enabled smartphones, the reality is that bandwidth speed is not guaranteed. Therefore, data services are sold on MB/GB rather than on mbps/gbps basis (Gillwald et al., 2018).

Affordability of data

Access and use depend centrally on the price of devices and price of service. Price reduction and /or subsidy are tools for making services affordable to consumers. Gillwald et al. (2018) found that 32% of non-users of the Internet cited high data cost. The main costs in internet access and use relates to both services and devices. For many subscribers, data bundles are just unaffordable. And those bundles which are seemingly affordable are tagged with short duration validity (see Tables 27-29). Final choices often come down to either spending household money on data bundle or on basic necessities like food. Internet-enabled smart phones have not penetrated the Nigerian population much. Most internet users and prospective users simply cannot afford such grade of phones. It is even a challenge to replace damaged or missing smaller phones, especially among rural subscribers.

Concerns about Content

Some users of the Internet are concerned about unsolicited and/or annoying contents that are shared on group platforms and open online pages. Some users have been reported to react by opting out of internet use completely. Such reactions are said to be more common with female internet users in Nigeria. The possibility of news being fake is an added concern

among social media users. Many parents either opt out or refuse to opt into internet use for fear their children may be negatively influenced through certain contents (Gillwald, 2017).

Privacy and security concerns
Privacy issues include harassment, slander, stalking of users. Security issues such as financial fraud, hacking and surveillance are of grave concern to many users. The study by Gillwald et al. (2012), however, showed that these concerns are higher among urban than rural subscribers.

Gendered issues
Married women, because of their several domestic chores, hardly have time to be online. Besides, several women complained in Africa about their husbands' discomfort with house wives being on social media (Gillwald et al., 2012).

Electricity
Phones, especially those internet-enabled, require constant power charging. Constant power supply is not the case, especially in many rural areas in Nigeria. Thus, many users are involuntarily offline due to power outage.

Illiteracy
Illiteracy, the inability to read and/or write is a widespread problem among non-users of the Internet. The languages in which online contents are written are a great impediment especially to non-users. An added constraint is the inability to "operate" the smart phone. Such skills may elude both literate and illiterate users. There are many literate users who lack the skill to manoeuvre the buttons and icons on smart phones because of poor prior access to computers. There is the need to have national policy that integrates digital skills training into education curricula from early school level (Gillwald, 2017).

Intellectual property rights in ICT
There are two types of IP in Nigeria, copyright and industrial. ICT regulation belongs to industrial property right. The global body for IP is the World Intellectual Property Organization (WIPO). Olubanwo and Oguntuase (2019) noted that there is no special functional body overseeing IP in Nigeria, but industry-specific oversight functions are in place. Notable among these are the Nigerian Copyright Commission, the Nigerian Broadcasting Commission; the Trademarks, Patents and Designs Registry; and the National Office for Technology Acquisition and Promotion. The Intellectual Property Office of Nigeria (IPON) is supposed to be the commercial law department in the Federal Ministry of Industry, Trade and Investment. IPON used to be financially semi-autonomous, having unhindered access to its fund, about 20% of the annual budget of the parent ministry. With the introduction of the single treasury account in 2015, however, access to fund became hard for IPON, leading to the loss of its autonomy and functionality. It has since become totally dependent on whatever the parent ministry surrenders to it.

Indeed, according to Aliyu (2018), the commercial law department does not have any specific budget for ICT regulation, beyond whatever support it receives from partner organizations, such as WIPO. This means that intellectual property rights approval and certifications are way behind the volume of applications received. The report by Aliyu (2018)

agreed with Olubanwo and Oguntuase (2019) who summarized the IP property challenges to include “low public awareness about what IP rights are protected under the law; ineffective mechanisms for the protection and enforcement of such rights; inadequate penalties for infringements; official corruption and lack of coordination among the various agencies of government involved in the development and protection of IP rights”.

Olubanwo and Oguntuase (2019) noted that ICT IP rights are highly violated in Nigeria with little or no deterrence. This is especially true of those related to internet and software piracy. The challenges listed against IP law enforcement in Nigeria include outdated laws, administrative bottlenecks at the Trademarks, Patents and Designs Registry, Nigeria’s non-membership of multinational IP organizations (e.g. African Regional Intellectual Property Organisation (ARIPO); the Yaoundé-based Organisation Africaine de la Proprié té Intelle ctuelle (OAPI); and the Geneva-based International Patent Cooperation Union (IPCU), formed based on the 1970 Washington Treaty – the Patent Cooperation Treaty (PCT); regulatory conflicts between national agencies; absence of deterrence against IP violations; and the lack of clear judicial procedure for punishing IP violations.

ICT Innovation hubs in Nigeria

NITDA was established in 2001 to regulate the IT sector in general. Through its sub-agency, Office for ICT Innovation and Entrepreneurship (OIIE), NITDA’s mandates include “develop, establish, support and incentivise ICT innovation hubs, information technology parks and community enterprise hubs across Nigeria; and collaborate with private sector, development partners and MDAs at both federal and state levels on policies and programmes that support ICT entrepreneurship and commercialization”. In its 2019 policy document, NITDA lays out 15 visions to be achieved within a framework of three broad areas (see Table 31). It is not clear how far the policy document containing the visions have translated into actions for implementation.

Table 31: Mandates and visions of the NITDA

Broad mandate	Visions
Digital Infrastructure	Vision 1: Incentivise telecommunication infrastructure sharing to achieve the economies of scale necessary for universal affordable access. Government will support private sector providers to merge their infrastructure.
	Vision 2: Drop Right of Way charges for fibre distribution and simplify administrative requirements to reduce capital requirements for expanding digital infrastructure, thereby reducing the costs passed on to consumers.
	Vision 3: Adopt a “dig once” policy, so that any traditional infrastructure investment--roads, electricity, water and so on--must be accompanied by optic fibre cables, where none already exist.
	Vision 4: Build a national data framework and harmonise e-Governance to enable innovation, improve efficiency, transparency, accountability and citizen participation in government:
	Vision 5: Support renewable energy through easily accessible

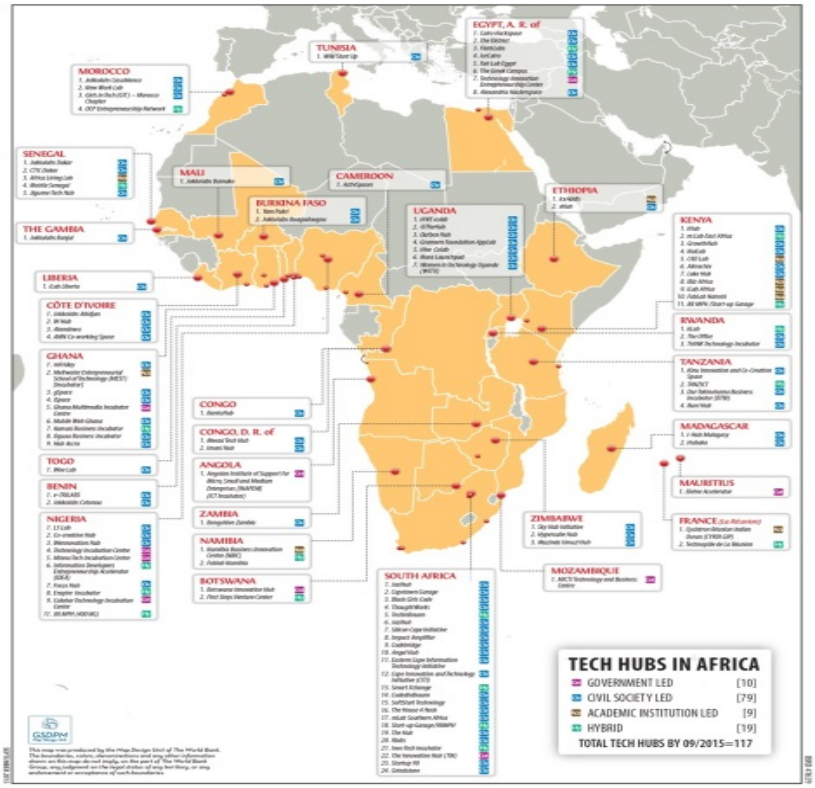
Broad mandate	Visions
	tax incentives for local production of renewable energy technology.
Education Reform, Skills Development and R&D	Vision 6: Reform the national education system and curricula to prepare the youth for a knowledge-based economy.
	Vision 7: Improve digital literacy, entrepreneurship and technical skills amongst youth to encourage digital job creation and empowerment:
	Vision 8: Support youth employment and participation in the private sector through tax incentives.
	Vision 9: Simplify immigration requirements for investors, foreign companies and other skilled professionals to start businesses (or invest) in Nigeria to facilitate exchange programs and collaborations.
	Vision 10: Establish inclusive public procurement policies for start-ups, this way the Government can directly seed fund pre-commercial private sector R&D.
	Vision 11: Expand Research and Development with adequate funding, adequate infrastructure, adequate institutional capacity, simplified tax incentives and alignment with national development plans.
Supporting the Ecosystem for Innovation and Entrepreneurship	Vision 12: Facilitate start-up growth by easing the business environment and simplifying access to opportunities for indigenous innovators:
	Vision 13: Provide support for hubs and linkages for nationwide collaborations.
	Vision 14: Incentivise venture capital and angel investment funds to invest in innovative entrepreneurship through simplified tax incentives
	Vision 15: Position Nigeria as a global hotspot for innovation through policy reform, messaging, and participation at global technology events

Source: NITDA (2019)

Kelly (2014) noted that "Africa's 700 million or so mobile subscribers use services that are provided locally, and they are also downloading more applications that are developed locally". He noted further that "one of the main sources of locally developed applications is the technology hubs that are springing up across Africa." A leading innovation hub in Nigeria is the co-creation hub. Tech hubs vary a lot in their scale, objectives and business models. Whatever their objectives, governments across Africa are getting more involved because they have shown potential for job creation.

Not all the innovation ideas incubated are sustained at implementation. Kelly (2014) observed a high failure rate among innovation techs. The Tinapa Knowledge City (TKC) project, an initiative of the Cross River State Government (CRSG), was created to facilitate knowledge and technology transfer to the broader local economy, thereby acting as a catalyst for job and wealth creation. The Mina Technology Incubation Centre, Nigeria, has a mission to develop the necessary infrastructures to nurture technology value-added and

technology-related activities within the state and to create enabling environment for effective linkage among technology, capital providers and entrepreneurs. L5Labs is a business incubator focused on building outstanding businesses in Africa. The focus is on the rapidly expanding mobile and internet technology space in Nigeria. L5Labs works with start-ups and early stages businesses led by teams, comprising individuals with outstanding leadership potential who are aiming to tap into very large identifiable markets.
The Technology Incubation Centre in Benin City has a broad mandate to assist small-scale budding entrepreneurs to overcome the initial hurdles of bringing viable research and development (R & D) results and other technologies into profitable enterprises. Venia Business Hub, Lagos , was established to make doing business in Nigeria practical, affordable and flexible for start-ups, SMEs, corporate organisations and multinationals, as well as link growing businesses to a pool of companies for financial support as and when required. Co-creation Hub Nigeria, or CcHUB, is Nigeria's foremost open living lab and pre-incubation space. It is designed to be a multi-functional, multipurpose space, where work to catalyse creative social tech ventures takes place. The Hub allows technologists, social entrepreneurs, government, tech companies, impact investors and hackers in and around Lagos to co-create new solutions to the many social problems in Nigeria.
The Wennovation Hub is a true sub-regional (mainly West African) hub for start-up business development located in Ikeja, Lagos, with a focus on synthesizing high impact start-up growth, facilitation and development. The hub provides office space, ongoing support, network and contacts, funding and affordable project support for innovative early-stage companies. Figure 11 shows the tech hubs across Africa (but for emphasis, this study has isolated Nigeria's information into Table 32).



Source: http://pubdocs.worldbank.org/pubdocs/publicdoc/2015/10/652861444073319429/AFC41639-9-25-15.pdf

Figure 11: Tech hubs across Africa

Table 32: Tech hubs in Nigeria

S/N	Tech hub	Establishment / management
1	L5 Lab	Civil society
2	Co-creation Hub	Civil society
3	Wennovation Hub	Civil society
4	Technology Incubation Centre G-led	Government
5	Minna Tech Incubation Centre	Government
6	Information Developers Entrepreneurship Accelerator (IDEA)	Hybrid or multi-agency
7	Focus Hub	Civil society
8	Enspire Incubator	Hybrid or multi-agency
9	The Tinapa Knowledge City (TKC) project	Government
10	88 MPH (400 NG)	Hybrid or multi-agency

Source: Collation from Figure 11 and http://pubdocs.worldbank.org

ICT start-up funds in Nigeria

As part of efforts to boost job creation, particularly among the youth, the Central Bank of Nigeria (CBN), in collaboration with the Bankers' Committee, recently introduced the Creative Industry Financing Initiative (CIFI) with a view to improving access to long-term low-cost financing for entrepreneurs and investors in the Nigerian creative and information technology (IT) sub-sectors. The CBN's Creative Industry Financing Initiative (CIFI) document, released in July 2019, essentially targets the boosting of youth employment by granting "access to long-term low-cost financing by entrepreneurs and investors in the Nigerian creative and information technology (IT) sub-sectors".

Among those targeted by the loan are start-ups engaged in the creative industry; and students of higher institutions engaged in software development. The initiative is to be funded from the Agri-Business Small, and Medium Enterprises Investment Scheme (AGSMEIS), an initiative of the Bankers' Committee, with a seed fund of ₦22.9 billion (CBN, 2019). The breakdown of this amount shows that student software development and information technology will receive ₦1 billion (4.4%) and ₦5.5 billion (24.0%) respectively. Under the student software development loan scheme, a single obligor can access ₦3.0 million at an all-inclusive interest of 9% per annum, with a 9-month repayment moratorium from the date of fund disbursement. The repayment source is the proceeds of software sale or patent usage.

Under IT start-up financing, items to be supported are equipment purchase and rental/service fees. Although the value of the support is not specified, an all-inclusive interest rate of 9% per annum is envisaged, with a moratorium of 36 months from the date of loan disbursement. A minimum of 20% equity contribution is built into the loan term, but no collateral is required beyond showing a good history of loan repayment. The participating financial institutions will be responsible for application processing, monitoring, risk bearing and loan recovery (CBN, 2019).

There is considerable momentum for venture capital build up in Nigeria. As noted by Jake Bright (2018), of the 22 African managed and located funds, 9 (or 41%) were formed since 2016 and 9 are in Nigeria. Furthermore, 22 (or 43%) of the 51 funds investing in African start-ups are headquartered in and managed by Africa. Some of the funds formed after 2016 are

Microtraction, Neon Ventures, Beta Ventures, and CcHub's. The size of the capital funds found among Africa-based investments varies between $25,000 and $10 million. The largest fund to an African tech went in 2018 to Kenyan Cellulant in the amount of $47.5 million by TPG's Growth Fund. Two of Nigerian funds that made Crunchbase's list of 51 are EchoVC (20th) and Ventures Platform (23rd). These are the funds with greatest investments in Nigeria during the review period.

At another policy level, the Nigerian Minister of Communication announced in 2018 that the sum of $15 million would be raised locally and internationally to support the potential of the ICT sector (VenturesAfrica, 2019). The high points in the minister's announcement are that beneficiaries of the fund will not require collaterals to access the fund; the fund will look out for commercially viable indigenous ideas and projects in ICT; and the fund will be managed privately, independent of government. The proposal is that the Nigeria Information Technology Development Agency (NITDA) will first invest $3.6 million, while the $11.4 million balance will be sourced from local and international investors.

Status of Ict4ag Services in Africa and Nigeria

The next two sub-sections provide the status of D4AG in Africa and Nigeria. Any continental report on the D4AG status in Africa obviously includes solutions from Nigeria, since most of the solutions reported to date are located in West Africa (Tsan et al., 2019).

A continental overview

The report by Tsan et al. (2019) showed that the potentially available agriculture market in Africa by 2018 was about £2.3 billion, of which only £127 million was realized. This presents a huge opportunity to tap into if necessary policies are formulated and rightly implemented in favour of digitalized agriculture. The number of SHFs registered as using a digital solution by 2019 across the continent was 33 million, but this number can potentially reach 200 million by 2030. A total of 41 D4AG solutions were available in 2012; this number spiralled to 390 by 2019.

Areas of potential roles for digitalization in agriculture include market linkages, advisory and information services, supply chain management and financial access. In order to realize the potential of digital solutions in agriculture, a host of infrastructure must be put in place. Tsan et al. (2019) listed D4AG to include agricultural data (e.g., farmer registries, farmer transactions, soil maps, weather, agronomy, pest and disease surveillance); D4Ag hardware (e.g., drone, satellite/ GIS, field sensors, machinery sensors, portable soil/crop/ input diagnostics); and D4Ag software (e.g., CRM, ERP, data capture tools, field agent management tools, data analytics tools, blockchain platforms).

Of the 390 D4AG solutions identified, the distribution was 13% for supply chain management; 35% for advisory and info services; 8% for D4Ag data intermediaries; 14% for financial access; 2% for macro agri-intelligence; and 27% for market linkages. On the basis of smallholder registration, the D4AG usage distributions across the continent was 68% for advisory and info services; 17% for financial access; 8% for market linkages and 7% for supply chain management. This analysis was based on estimated 33.1 million SHF registrations across Africa.

The available D4AG solutions are spread across at least 43 SSA countries, with East Africa (especially Kenya) accounting for more than 50% of all registered farmers using the

solutions. Across the West African G5 Sahel, about 27 solutions are assumed to benefit about 573,000 users; some other 33 solutions are potentially upcoming (Tsan et al., 2019). According to African Business Online (2019), the state of knowledge about D4AG at the continental level is that: women are underrepresented, accounting for less than 30% access to the total registered digital solution users in Africa; the youth accounts for about 70% of all registered users across Africa; and West Africa accounts for most of the available digital solutions, while East Africa accounts for more registered users than West Africa. This highlights gender, age and regional divide in the usage of digital solutions in African agriculture.

Challenges to D4AG in Africa

- The development of D4AG technologies is out-pacing human capacity development in many countries. There is need for people to understand the solutions they intend to take to the users; this knowledge is mostly a constraint, according to CTA (2019). Also, digital literacy among prospective users is grossly low, and this can affect adoption rate.
- Many African D4AG service providers have not made it to profit levels; they still rely on donor support to exist. This does not encourage long-term sustainability. The core challenge is the unwillingness of users (SHFs) to pay for private services, because of historic dependence on free public sector agricultural services. Thus, business models that encourage SH users to pay will need to be evolved, if D4AG services are to survive.
- Data are grossly lacking on farmer registration, agronomic practices, soil properties, surveillance on pests and diseases and weather. Without databases on these, especially with public investments, costs of service delivery will be unbearable for D4AG private providers. The aspiration is that D4AG need to reach the users, thrive and make sustained impacts.
- Telecom operators still largely focus their infrastructure investments in capital cities and urban organizations, and rarely in the remote agricultural sector. The same pattern is largely followed by donors and D4AG investors, because it is hard to invest in access infrastructures as a pre-condition for delivering D4AG services to users. The consequence is that SHFs will be perpetually left out of the D4AG space, unless and until the right policies are formulated and implemented to boost public-private investment in critical infrastructure.

Recommendations

- Digital literacy and skills are lacking at various levels, among users, policy formulators and implementers. Thus, training and retraining will need to be built into the government agenda for promoting D4AG at various levels, including the users along the D4AG value chain (farmers, extension agents, youth participation in incubator initiatives, government ministry staff). Donors may consider partnering local skills development initiatives of D4AG in the public and private sectors, and possibly in-build this into the grants. Investors have a role to play by partnering with enterprises to ensure explicit inclusion of digital and skills training in their D4AG agenda.
- Towards long-term sustainability of D4AG, it is important to evolve business models that work. Among other pathways, it is needed to fund alternative business models, conduct studies on their impacts and share the outcomes among individual and

consortia organizations. This, for example, will move investments into otherwise high-risk but positively-impacting businesses.

- There is need to promote inclusive D4AG services. Government, on its part, may investment in rural infrastructure to encourage private D4AG investment where youths and woman are largely found. Donors and investors may tie grants and investments to targets defined around youth and women inclusion in D4AG projects, and with clear rural/urban representation.
- Some intermediate but critical data are not available within the D4AG space; this tends to affect real time service delivery. They include remote sensing and farmer-specific data. Having real time availability of these and other data requires multi-stakeholder investments. Government may act through its local research agencies to improve their funding. Donors may need to partner government and local research initiatives, including data management capacity building. Investors need to partner government agencies that generate public goods, e.g. weather data, with funding and training.
- Investment should be undertaken on useful D4AG research. Such research need to be relevant to farm business situations, bringing out success and failure factors in various value chains involving D4AG and sharing results on impact assessments of adopting D4AG solutions along various value chains.
- D4AG initiatives are still largely localized and fragmented within countries and across the African continent. There is the need to pool knowledge and databases and impact results, to avoid repeating investments on already-achieved results elsewhere. Collaboration between government, donors and investors in each country and across countries will help eliminate wasteful investments and research duplications.

Continental outlook

- The prospects of expanded use of advanced technologies within the D4AG space (drones, blockchain, machine learning) is bright, since respondents were already reporting access to them.
- Lowering the cost of service provision licence will further lower cost of access to users. In this regard, it is noteworthy that big tech names (Microsoft, Google, IBM, Bosch Alibaba, Bayer, Syngenta, Yara, John Deere and UPL) have already entered the D4AG space. This development is likely so speed up, taking D4AG to even a greater scale.
- The current focus of D4AG is to increase access to solutions and register more users under different solutions. As the registration expands, the focus could shift towards greater use and evaluation of impacts.

Status of D4AG in Nigeria

A number of ICT service providers have included Nigeria as their operational space. Some are more visible in the agricultural space than others. These companies with presence in Nigeria include: Crest Agro-processing project, Beat Drone, Kitovu, Paga, Kiakia, Hello Tractor, Farmcrowdy , Releaf, Thriveagric, Mysmartphone, DSI Technologies Limited, E-Farms, Quick Leap, Payfarmer and Cellulant. Their online profiles suggest that most of these ICT service providers serve the agricultural sector. The online profiles of these service providers are presented in Appendix A to this report. Those ICT service providers with documented

agricultural services were then reviewed. These were: Hello Tractor, Farmcrowdy, Kitovu, E-farms, ThriveAgric and Cellulant. Farmcrowdy, Kitovu, E-farms, and ThriveAgric were selected for detailed exploration as case studies.

Tractor hire services

The unexplained paradox is that SSA owns 60% of the global uncultivated farmland, but the yields of most crops fall well below those observed outside the African continent (Oliver and Lohento, 2019). Yet, productivity increase is the only way to get SSA out of poverty.

Low level of mechanization has been cited as a key factor in low agricultural productivity in SSA. Indeed it is estimated that SSA is achieving only 50% of its productivity potential due to low mechanization. Hello Tractor has attempted to fill this gap through the use of 'Internet-of-Things' (IoT) digital solution which involves linking tractor owners, farmers and agents who book for tractors. Based on expressed demand, agents aggregate the individual demand and submit same to tractor owners/ operators. This facilitates speedy access to tractor services (Oliver and Lohento, 2019).

Young people from rural communities are trained in the use of the apps to connect idle tractors to farmers who need them while ensuring employment for the youth. There is a platform on which farmers' tractor demands are aggregated and shared with tractor owners and services are offered based on the tractors closest to the farmer.

Oliver and Lohento (2019) estimated that Hello Tractor controls 75% of private tractor services in Nigeria; through this initiative some 250,000 farmers have been reached. In partnership with CTA, Hello Tractor has organized tractor demos in various parts of Nigeria towards awareness creation, specifically in Adamawa, Oyo, Ogun and Kwara states. Capacity building events were organized for agents on the use of digital devices, including videos, website and apps. These devices help aggregate markets and manage tractor hiring services.

Marketplace solutions

Cellulant Nigeria is in the forefront of providing marketplace platform for players in the input market (farmers, agro-dealers, financial institutions, governments, development partners) and output market (e.g. produce assemblers). The platform is called Agrikore, which is powered by the Tingg payments platform. This digital solution is an initiative aimed at aggregating otherwise fragmented market participants (AgroNigeria, 2019; Akinfenwa, 2019).

The Case Studies for D4AG in Nigeria

The survey instruments leading to the following results were based on the protocol shared among RC 3 cluster countries. The list of services offered by the Agri-techs was based on their respective online profiles (Appendix A & Appendix B). As pointed out earlier, only two Agri-techs, ThriveAgric and E-Farms, granted access to their farmers. However, Kitovu and FarmCrowdy granted organization interviews. The outcomes of the various surveys are reported and discussed in this section. Starting with the organizational interviews, the results are categorised into services rendered, ICT deployment, and narratives in terms of main successes and reasons for successes, challenges and likely sources of the challenges.

The Agri-techs

Kitovu

Services rendered

Kitovu, located in Iseyin, Oyo State partners mainly with youth and smallholders who are the main beneficiaries of its services. Details of the services rendered are presented in Table 33. Services are rendered through farmer-based organizations (FBOs), and includes soil geo-location data collection, analysis, aggregation; provision of fertilizers and other agro-chemicals, and seedlings; market access for farmers' produce; information on what crops processors want; information on crop quality specifications, best inputs to use, where to source inputs, agricultural best practices, and access to extension services. The value chain activities covered by the services include input provision, on-farm production and post-harvest activities, such as marketing.

Table 33: Summary of services offered by Kitovu

S/N	Services offered	Target users	Target value chain activity
1	Soil geo-location data collection, analysis, aggregation	youth, smallholders (uses FBOs platform)	input provision
2	Provision of right fertilizers, agro-chemicals, and seedlings	youth, smallholders (uses FBOs platform)	input provision
3	Market access for Farmers' products	youth, smallholders (uses FBOs platform)	Marketing
4	Information to farmers on what crops processors want	youth, smallholders (uses FBOs platform)	Production (post-harvest)
5	Information to farmers on crop quality specifications	youth, smallholders (uses FBOs platform)	Production (post-harvest)
6	Information to farmers on the best inputs to use	youth, smallholders (uses FBOs platform)	input provision, Production
7	Information to farmers on where to source inputs	youth, smallholders (uses FBOs platform)	input provision, Production
8	Information to farmers on agricultural best practices	youth, smallholders (uses FBOs platform)	input provision, Production
9	Access to extension services	youth, smallholders (uses FBOs platform)	production (pre-harvest)

Source: Organizational interview, 2019

ICT deployment

Table 34 shows data on awareness and usage of the listed ICT items. This organization used 11/25 ICT items to render services, namely, global positioning system (GPS), satellites, sensors ,camera ,mobile phone, smartphone app, webpage, email, machine learning, artificial intelligence, and agent network. These items were used for data collection, data analysis and information dissemination.

Main successes and Challenges

The Agri-tech (Kitovu) was asked to give narratives about their successes and challenges (Table 35). The main successes were: tripling of smallholder yields from 1.2mt/ha to 3.9mt/ha, guaranteeing market access to users, leading to less post-harvest losses, and smallholder production expansion. The main factors accounting for the organization's successes were reliable data for decision making, precision agriculture and yield increases. For emphasis, yield increase accounted for production expansion than area increase. However, there were no farmer data to verify this.

The main challenges facing the Agri-tech included farmers' inability to afford services; organization's poor access to credit, it could not on-lend to farmers; and partner organizations were not coherent in messages passed to farmers. The main sources of these challenges were policy changes with new governments and lack of policies to guarantee product prices.

Table 35: Usage of ICTs by Kitovu

ICT Items	Ever used to serve?	Specific use of ICT item
Global Positioning System (GPS)	yes	Data collection
Satellites	yes	Data collection
Sensors	yes	Data collection
RFID	no	Not applicable
Camera	yes	data collection
Voice recorder	yes	Not applicable
Mobile phone	No	Not applicable
Short Message Service (SMS)	No	Not applicable
USSD	No	Not applicable
Call centre	No	Not applicable
Interactive voice Response (IVR)	No	Not applicable
Smartphone app	yes	data collection, analysis
Webpage	yes	Info dissemination
Email	yes	Info dissemination
e-widgets	No	Not applicable
Machine learning	yes	data analysis
Artificial intelligence	yes	data analysis
Behavioural biometrics	No	Not applicable
Blockchain technology	No	Not applicable
Point of Sale Terminals (POS)	No	Not applicable
Automated Teller Machines (ATMs)	No	Not applicable
Cards	No	Not applicable
Agent network	yes	data collection, info dissemination
Check out APIs for e-commerce	No	Not applicable

Source: Organizational interview, 2019

Table 35: Main successes and challenges of Kitovu

Main successes	1	Smallholder yield 1.2mt/ha to 3.9mt/ha (triple)
	2	Guaranteed market access; less post-harvest losses
	3	Stallholder production expansion
Main reasons for successes	1	Reliable data for decision making
	2	Precision agriculture
	3	Yield increases
Main challenges	1	Farmers unable to afford services
	2	Organization lacks access to credit; so cannot onlend to farmers
	3	Partner orgs not coherent in messages passed to farmers
Main sources of challenges	1	Government policies changes with new governments
	2	Lack of policies to guarantee product prices
	3	No policies to regulate input adulteration

Source: Organizational interview, 2019

FarmCrowdy:

Services rendered:
FarmCrowdy, with headquarters in Lagos, partners mainly with produce buyers, smallholder farmers, investors, input sellers, insurance companies, investors, commercial farmers, and graduate farmers; these re the main beneficiaries of its services. Details of the services rendered are presented in Table 36 and include market access to produce, empowerment of rural farmers, use of customized app for data collection from farmers and farms, linkage of farmers to insurance coverage, crowd funding of capital for smallholder farmers, platform for peer to peer investment, training of graduate farmers, linkage of farmers to local processors and produce off-takers and connection of commercial farmers to investors. The value chain activities covered by these services include marketing, input supply, R&D, production (pre- & post-harvest), distribution/transport

Table 36: Summary of services offered by FarmCrowdy

S/N	Service	Target users	Target value chain activity
1	Market access for Farmers' products	Produce buyers, smallholder farmers, Investors	Marketing
2	Empowerment of rural farmers	Input sellers, produce buyers, Insurance coys, Investors	Input supply, Production (pre- & post-harvest)

S/N	Service	Target users	Target value chain activity
3	Use of customized app for data collection from farmers and farms	Smallholder farmers, investors	Input supply, Production (pre- & post-harvest)
4	Linkage of farmers to insurance coverage	Insurance companies	Production (pre- & post-harvest)
5	Crowdfunding of capital for smallholder farmers	Investors	R&D
6	Platform for Peer to peer investment	Commercial farmers, Investors	Production (pre- & post-harvest)
7	Training of graduate farmers	Graduate farmers	Production (pre- & post-harvest)
8	Linkage of farmers to local processors and produce off-takers	produce buyers	distribution/transportation
9	Connection of commercial farmers to investors	Commercial farmers, Investors	Production (pre- & post-harvest)

Source: Organizational interview, 2019

ICT deployment

Table 37 shows the responses on usage of the listed ICT items for services. This organization used 8/25 ICT items, including global positioning system (GPS), camera, mobile phone, call centre, smartphone app, webpage, email and check out APIs for e-commerce. The uses of these items included data collection, data analysis, investment platform and information dissemination.

Table 37: Usage of ICTs by FarmCrowdy

ICT Items	Use ICT item?	Specific use of ICT item
Global Positioning System (GPS)	Yes	data collection, analysis
Satellites	No	Not applicable
Sensors	No	Not applicable
RFID	No	Not applicable
Camera	Yes	data collection
Voice recorder	No	Not applicable
Mobile phone	Yes	data collection, analysis
Short Message Service (SMS)	No	Not applicable
USSD	No	Not applicable
Call centre	Yes	data collection, analysis, info dissemination
Interactive voice Response (IVR)	No	Not applicable
Smartphone app	Yes	data collection, analysis
Webpage	Yes	Investment platform
Email	Yes	data collection, analysis, info dissemination
e-widgets	No	Not applicable
Machine learning	No	Not applicable
Artificial intelligence	No	Not applicable

ICT Items	Use ICT item?	Specific use of ICT item
Behavioural biometrics	No	Not applicable
Blockchain technology	No	Not applicable
Point of Sale Terminals (POS)	No	Not applicable
Automated Teller Machines (ATMs)	No	Not applicable
Cards	No	Not applicable
Agent network	No	Not applicable
Check out APIs for e-commerce	Yes	data collection, analysis

Source: Organizational interview, 2019

Main successes and Challenges

FarmCrowdy was asked to narrate its successes and challenges. In Table 38, the main successes included empowerment of over 11,000 farmers, over 35,000 sponsored farms, and use of organisation's website and mobile app for the sponsorship of farms. There was no means, however, to independently verify this because the researchers were denied access to any farmer or organization. The main factors accounting for the successes, according to the organization, includes good database, servers and human resources; and successful connection of farmers to investors. The main challenges of the Agri-tech were poor access of farmers to smartphones, poor network connectivity in rural areas and language barrier. The main sources of these challenges were poor infrastructure and inadequate knowledge of ICT-enabled technologies among users.

Table 38: Main successes and challenges of FarmCrowdy

Main successes	1	Empowerment of over 11,000 farmers
	2	Over 35,000 sponsored farms
	3	Use of org's website and mobile app by farm sponsors to sponsor farms
Main reasons for successes	1	Well equipped with database, servers and human resources
	2	Successful connection of farmers to Investors
Main challenges	1	Poor access of farmers to smartphones
	2	Poor network connectivity in rural areas
	3	Language barrier
Main sources of challenges	1	Poor infrastructure
	2	Inadequate knowledge of ICT-enabled technologies among users

Source: Organizational interview, 2019

End-user survey results

ThriveAgric Farmers

ThriveAgric, with headquarters in Abuja, granted this study generous access to 50 farmers, although 20-25 was suggested. The farmers interviewed were located in Giwa, Kaduna State; they partnered with the Agri-tech mainly on crop value chain activities.

Value chain engagements of farmers

Table 39 shows the value chain engagements of ThriveAgric farmers. The results available show that 80-100% of the farmers engaged in crop farming, livestock farming, input buying, wholesaling, sorting/ grading and transporting / distribution. Less than 40% of the farmers engaged in input supplying, agro-processing, packaging and exporting.

Table 39: Percentage of farmers engaged in the value chain activities listed

Value chain activities	% yes (n=50)
Crop farming	100.0
Livestock farming	88.0
Input buying	100.0
Input supplying	32.0
Wholesaling	92.0
Agro-processing	20.0
Packaging	4.0
Sorting / grading	100.0
Assembling	44.0
Transporting / distribution	96.0
Exporting	4.0

Source: ICT users survey, 2019

Services received:

Table 40 shows the list of services offered by ThriveAgric and the percentage of beneficiaries in each service. The list of services was based strictly on what was provided on the Agri-tech's website (Appendix A and B). At least 80% of the farmers received services on market access to produce, information on agricultural best practices, use of customized app for data collection from farmers and farms, delivery of automated SMS to farmers on farm progress, linkages to insurance coverage, and linkages to local processors and produce off-takers. The results also show that 72-76% of the farmers received such services as extension access, satellite information on soil condition and for predictions on weather conditions and yields.

Table 40: Percentage of farmers benefitting from indicated ICT-enabled services from ThriveAgric

S/N	Function / Activity	% yes (n=50)
1	Market access for Farmers' products	96.0
2	Information to farmers on agricultural best practices	100.0
3	Access to extension services	76.0

S/N	Function / Activity	% yes (n=50)
4	Use of customized app for data collection from farmers and farms	80.0
5	Delivery of automated SMS to farmers on farm progress	92.0
6	Satellite information soil condition	72.0
7	Satellite information for predictions on weather conditions and yield	76.0
8	Linkage of farmers to insurance coverage	84.0
9	Linkage of farmers to local processors and produce off-takers	100.0

Source: ICT users survey, 2019

Awareness, sources of knowledge and relevance of ICT services:

Table 41 shows the distribution of farmers by awareness, sources of knowledge and assessment of relevance of ICT-enabled services. At least 90% of the farmers were aware of: market access to farm produce, information on agricultural best practices, delivery of automated SMS to farmers on farm progress, linkage of farmers to insurance coverage, and linkage of farmers to local processors and produce off-takers. The results also shows 72-76% of the farmers were aware of extension access, satellite information on soil condition and satellite information for predictions on weather conditions and yield.

The data show at least 90% of the farmers indicated ThriveAgric as their source of awareness about market access to farm produce, information on agricultural best practices, delivery of automated SMS to farmers on farm progress, linkage to insurance coverage and to local processors and produce off-takers. Between 72% and 76% of the farmers knew from ThriveAgric about the use of customized app for data collection from farmers and farms, satellite information on soil condition and predictions on weather conditions and yields. The source of knowledge on extension services was also ThriveAgric, according to 68% of the farmers.

Farmers were asked to rate each service as not very relevant (NVR), not relevant (NR), undecided (U), relevant (R) , very relevant (VR) or not applicable (NA). In Table 41, services for which at least 80% of the farmers rated as relevant or very relevant were market access to farmers' produce, information on agricultural best practices, delivery of automated SMS to farmers on farm progress, and linkage to local processors and produce off-takers. The application of satellite information to predicting weather conditions and yields, and linkage of farmers to insurance coverage were also rated as relevant by 72 % of the farmers; also, 64-68% of the farmers rated relevant access to extension services, use of customized app for data collection from farmers and farms, and satellite information on soil condition.

Table 41: Distribution of farmers by awareness, sources of knowledge and assessment of relevance of ICT-enabled services

S/N	Service	%aware (n=50)	%aware from ICT org (n=50)	Relevance of service assessment (n=50)					
				NVR %	NR %	U %	R %	VR %	%NA
1	Market access for Farmers' products	96.0	96.0				36.0	60.0	4.0
2	Information to farmers on agricultural best practices	100.0	100.0				40.0	60.0	

S/N	Service	%aware (n=50)	%aware from ICT org (n=50)	Relevance of service assessment (n=50)					
				NVR %	NR %	U %	R %	VR %	%NA
3	Access to extension services	72.0	68.0			4.0	36.0	32.0	28.0
4	Use of customized app for data collection from farmers and farms	76.0	76.0		4.0		28.0	40.0	28.0
5	Delivery of automated SMS to farmers on farm progress	92.0	92.0			4.0	48.0	40.0	8.0
6	Satellite information soil condition	72.0	72.0			12.0	48.0	16.0	24.0
7	Satellite information for predictions on weather conditions and yield	76.0	76.0			4.0	52.0	20.0	24.0
8	Linkage of farmers to insurance coverage	88.0	88.0			16.0	52.0	20.0	12.0
9	Linkage of farmers to local processors and produce off-takers	100.0	100.0				52.0	48.0	

Source: ICT users survey, 2019

Awareness, usage and understanding of ICT devices by farmers

Table 42 shows the distribution of farmers by awareness, usage and assessment of understanding of indicated ICT devices among the respondents. At least 90% of the farmers indicated awareness of global positioning system (GPS), satellites, sensors, camera, voice recorder, mobile phone, short message service (SMS), unstructured supplementary service data (USSD), call centre, interactive voice response (IVR), smartphone app, email, behavioural biometrics, point of sale terminal (POS), automated teller machines (ATMs) and cards. Website was known to 76% of the respondents, while 64% of them knew about radio frequency identification (RFID) tags and Blockchain technology. Artificial intelligence was known to 52% of the farmers.

As for usage, 90% or more of the respondents indicated that the Agric-tech served them with global positioning system (GPS), satellites, sensors, camera, voice recorder, mobile phone, short message service (SMS), unstructured supplementary service data (USSD) , call centre, interactive voice response (IVR), smartphone app, email, point of sale terminals (POS), automated teller machines (ATMs) and cards. Webpage and behavioural biometrics served 72-76% of the respondents, while 60-64% were served with radio frequency identification (RFID) tags and Blockchain technology.

The farmers were asked to rate each of the listed ICT items as either not easily understood (NEU), not understood (NU), undecided (U), easily understood (EU), very easily understood (VEU) or not applicable (NA). The ICT items for which 80% or more of the farmers rated as EU or VEU were global positioning system (GPS), satellites, sensors, camera, voice recorder, mobile phone, short message service (SMS), unstructured supplementary service data (USSD), call centre, interactive voice response (IVR), smartphone app, email, point of sale

terminals (POS), automated teller machines (ATMs) and cards. Radio frequency identification (RFID) tags, webpage and Blockchain technology were rated as EU or VEU by 60-68% by the farmers.

Capacity building and mode of service delivery

In response to group membership status, all respondents indicated being a member of farmers organization. Table 43 shows the distribution of farmers by service-related training and mode of service delivery (individual or group). The results show that 80% or more of the farmers received training on market access for farmers' products, information to farmers on agricultural best practices, delivery of automated SMS to farmers on farm progress, linkage of farmers to insurance coverage and linkage of farmers to local processors and produce off-takers. Training on access to extension services, use of customized app for data collection from farmers and farms, satellite information on soil condition and predictions on weather conditions and yield was received by 72-76% of the respondents.

On how services were delivered, at least 80% of the farmers indicated that groups received services relating to market access for farmers' products, information to farmers on agricultural best practices, linkage of farmers to insurance coverage and to local processors and produce off-takers. Access to extension services, use of customized app for data collection from farmers and farms, delivery of automated SMS to farmers on farm progress, satellite information on soil condition and predictions on weather conditions and yield. The essential trend in the results is that services were delivered mainly through groups.

Table 42: Distribution of farmers by awareness, usage and assessment of understanding of indicated ICT devices, ThriveAgric

S/N	ICT device	%aware (n=50)	% farmers served by ICT org (n=50)	Rating of ICT understanding (n=50)					
				NES %	NU %	U %	EU%	VEU %	NA
1	Global Positioning System (GPS)	100.0	96.0	0.0	4.0	4.0	56.0	32.0	4.0
2	Satellites	96.0	96.0	0.0	12.0		48.0	36.0	4.0
3	Sensors	96.0	96.0	0.0	4.0	4.0	48.0	36.0	8.0
4	Radio Frequency Identification (RFID) tags	64.0	64.0	0.0	0.0	0.0	36.0	32.0	32.0
5	Camera	100.0	100.0	0.0	0.0	0.0	40.0	60.0	0.0
6	Voice recorder	100.0	100.0	0.0	0.0	0.0	36.0	64.0	0.0
7	Mobile phone	100.0	100.0	0.0	0.0	0.0	28.0	72.0	0.0
8	Short Message Service (SMS)	100.0	100.0	0.0	0.0	0.0	28.0	72.0	0.0
9	Unstructured Supplementary Service Data (USSD)	100.0	92.0	0.0	0.0	0.0	16.0	76.0	8.0
10	Call centre	100.0	92.0	0.0	0.0	0.0	36.0	56.0	8.0
11	Interactive voice Response (IVR)	100.0	100.0	0.0	4.0	0.0	56.0	40.0	0.0
12	Smartphone app	100.0	100.0	0.0	4.0	0.0	52.0	44.0	0.0
13	Webpage	76.0	76.0	0.0	0.0	0.0	32.0	36.0	32.0

S/N	ICT device	%aware (n=50)	% farmers served by ICT org (n=50)	Rating of ICT understanding (n=50)					
				NES %	NU %	U %	EU%	VEU %	NA
14	Email	92.00	92.0	0.0	0.0	0.0	32.0	60.0	8.0
15	e-widgets	28.0	28.0	0.0	0.0	0.0	20.0	16.0	64.0
16	Machine learning	44.0	44.0	0.0	0.0	0.0	16.0	24.0	60.0
17	Artificial intelligence	52.0	28.0	0.0	0.0	4.0	16.0	8.0	72.0
18	Behavioural biometrics	92.0	72.0	0.0	0.0	8.0	32.0	28.0	32.0
19	Blockchain technology	64.0	60.0	0.0	0.0	0.0	32.0	24.0	44.0
20	Point of Sale Terminals (POS)	96.0	92.0	0.0	0.0	4.0	40.0	48.0	8.0
21	Automated Teller Machines (ATMs)	100.0	92.0	0.0	0.0	0.0	44.0	48.0	8.0
22	Cards	100.0	92.0	0.0	0.0	0.0	36.0	56.0	8.0
23	Agent network	28.0	24.0	0.0	0.0	0.0	8.0	16.0	76.0
24	Check out Application Programming Interface (APIs) for e-commerce	48.0	48.0	4.0	0.0	0.0	24.0	16.0	56.0

Source: ICT users survey, 2019

Table 43: Distribution of ThriveAgric farmers by service-related training and mode of service delivery

S/N	Service	% trained on service (n=50)	How services are delivered (n=50)		
			%group	%individual	% NA
1	Market access for Farmers' products	96.0	96.0	0.0	4.0
2	Information to farmers on agricultural best practices	100.0	100.0	0.0	0.0
3	Access to extension services	72.0	72.0	0.0	28.0
4	Use of customized app for data collection from farmers and farms	76.0	76.0	0.0	24.0
5	Delivery of automated SMS to farmers on farm progress	88.0	76.0	16.0	8.0
6	Satellite information soil condition	72.0	72.0	0.0	28.0
7	Satellite information for predictions on weather conditions and yield	72.0	72.0	0.0	28.0
8	Linkage of farmers to insurance coverage	80.0	80.0	0.0	20.0
9	Linkage of farmers to local processors and produce off-takers	100.0	100.0	0.0	0.0

Source: ICT users survey, 2019

Preliminary assessment of ICT impacts

The inclusion of this section in the survey was not from the protocol shared, but from curiosity and professional point of view. For the ThriveAgric farmers, assessment was done for crop, crop output, crop yield and household income. The crop-based assessments covered the four crops found in the survey (cowpea, sorghum, rice and tomatoes) among the farmers. The results in Table 44, based on paired t-tests, show that mean areas and outputs statistically increased for the four crops among the farmers, which they attributed to ICT exposure. All increases were significant at the 1% level. As for crop productivity (yield/ha), there was yield gains for sorghum, maize and tomatoes, but these were statistically insignificant. The yield loss was also statistical insignificant for beans and rice farmers. Thus, if the productivity gains or losses were statistically insignificant, a tentative inference was that the statistically significant gains in crop outputs came mainly from area expansion or from factors outside this survey. The survey did not explore how areas were gained, because this was an ex post discovery.

Table 45 shows the sources of household income. As expected, and consistent with Table 40, all the respondents derived income from crops and 88% derived income from livestock keeping. The other suggested income sources were largely suppressed in percentage values. In Table 46, the paired t-test shows that household income increased on the average from NGN871,640.00 to NGN1,480,680.00 per annum, attributed to ICT by the respondents. The mean difference was significant at the 1% level.

Table 44: Simple impact assessment of ICT on crop productivity variables

Production variable	Sample estimate	Beans	Sorghum	Maize	Rice	Tomatoes
Crop area (ha)	Value before ICT	.88	.78	1.24	.98	.63
	Value after ICT	1.44	1.33	2.06	1.39	1.14
	Sample size	32	18	48	38	42
	Mean difference	.56	-.56	-.82	-.41	-.51
	t-value	-7.31	-8.09	-12.29	-5.71	-14.48
	df	31	17	47	37	41
	2-tailed sig.	.000	.000	.000	.000	.000
Crop output (Kg)	Value before ICT	2162.5	2600.0	6037.5	4889.5	4009.5
	Value after ICT	4156.3	4588.9	10983.3	8328.9	8876.7
	Sample size	32	18	48	38	42
	Mean difference	-1993.8	-1988.9	-4945.8	-3439.5	-4867.1
	t-value	-8.04	-6.13	-3.33	-3.77	-4.20
	df	31	17	47	37	41
	2-tailed sig.	.000	.000	.002	.001	.000

Production variable	Sample estimate	Beans	Sorghum	Maize	Rice	Tomatoes
Crop yield (Kg/ha)	Value before ICT	3148.9	3129.7	3670.2	5450.0	7685.7
	Value after ICT	3069.8	3542.6	4045.8	5304.4	7925.7
	Sample size	32	18	48	38	42
	Mean difference	79.1	-412.9	-375.7	145.6	-240.0
	t-value	.39	-1.59	-1.40	.41	-.51
	df	31	17	47	37	41
	2-tailed sig.	.693	.131	.167	.684	.611

Source: ICT users survey, 2019

Note: In constructing the paired t-test, the mean outcome 'after' was subtracted from the mean outcome 'before' ICT; hence, the negative t-values where the mean outcomes 'after' were higher.

Table 45: Distribution of farmers by sources of income

Income source	% receiving (n=50)
Sale of crops	100.0
Sale of livestock and products e.g. dairy	88.0
Sale of other products e.g firewood, trees	8.0
Regular/salary employment	24.0
Agro-processing	16.0
Marketing / trading	28.0
Casual employment (agriculture)	4.0
Casual employment (non-agriculture)	0.0
Running own business	24.0
Remittances (e.g. money sent to respondent from relatives in the cities or from abroad)	4.0

Source: ICT users survey, 2019

Table 46: Simple Impact assessment of ICT on farmer income

Income variable	Sample estimate	Estimator
Total income per annum (NGN)	Value before ICT	871,640.00
	Value after ICT	1,480,680.00
	Sample size	50
	Mean difference	-609,040.00
	t-value	-8.79
	df	49
	2-tailed sig.	.000

Source: ICT users survey, 2019

Note: In constructing the paired t-test, the mean outcome 'after' was subtracted from the mean outcome 'before' ICT; hence, the negative t-values where the mean outcomes 'after' were higher.

E-Farm Farmers

E-Farms, located in Iseyin, Oyo State, granted access to their fish farmers. The farmers, all located in Ilora, Oyo State, partnered E-farms on fish farming.

Value chain engagements of farmers

Table 47 shows the value chain activities of the E-Farms farmers. The results show that: all the farmers in the sample engaged in fish farming, and 33.3% of them practice crop farming. The other value chain activities of the farmers were input buying (16.7%), mainly fish feed and fish medications. Wholesaling was practised by 25% of the farmers. No other value chain activity was found among the respondents.

Table 47: Percentage of farmers engaged in the value chain activities listed

Value chain activities	% yes (n=24)
Crop farming	33.3
Livestock/fish farming**	100.0
Input buying	16.7
Input supplying	0.0
Wholesaling	25.0
Agro-processing	0.0
Packaging	0.0
Sorting / grading	0.0
Assembling	0.0
Transporting / distribution	0.0
Exporting	0.0

Source: ICT users survey, 2019

**E-farms supported only fish farmers in the study area

Services received from E-farms:

Table 48 shows the list of services offered by E-farms and the percentage of beneficiaries for each service. The list of services was based strictly on what was provided on the Agric-tech's website. Provision of information on agricultural best practices by the Agri-tech was indicated by 75% of the respondents, while access to extension services was indicated by 50% of them. Linkage to local processors and produce off-takers was indicated by 16.7% of the respondents. None of the respondents appeared to have benefitted from other services in the table.

Table 48: Percentage of farmers benefitting from indicated ICT-enabled services from E-farms

S/N	Function / Activity	% yes (n=24)
1	Market access for Farmers' products	0.0
2	Information to farmers on agricultural best practices	75.0
3	Access to extension services	50.0
4	Crowdfunding of capital for smallholder farmers	0.0
5	Platform for Peer to peer investment	0.0
6	Training of graduate farmers	0.0
7	Linkage of farmers to local processors and produce off-takers	16.7

Source: ICT users survey, 2019

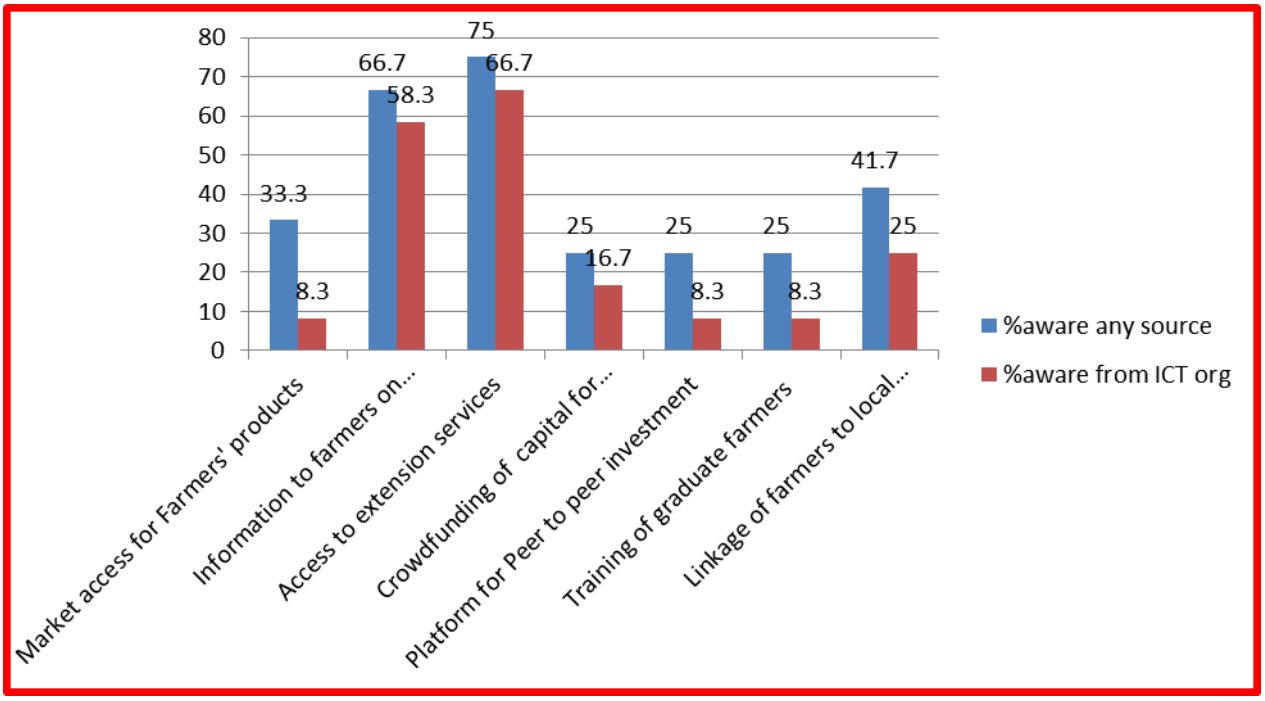
Awareness, sources of knowledge and relevance of ICT services

Table 49 shows the distribution of farmers by awareness, sources of knowledge and assessment of relevance of ICT-enabled services. Awareness of the services listed, irrespective of the sources, were found for: market access for farmers' products (33.3%); information to farmers on agricultural best practices (66.7%); access to extension services (75.0%); crowdfunding of capital for smallholder farmers (25.0%); platform for peer to peer investment (25.0%); training of graduate farmers (25.0%) and linkages to local processors and produce off-takers (41.7%). The enquiry sought to know whether the respondents were aware of each service, irrespective of the source. The awareness rate of the services through E-farms was: Market access to farmers' produce (8.3%); information to farmers on agricultural best practices (58.3%); access to extension services (66.7%); crowdfunding of capital for smallholder farmers (16.7%); platform for peer to peer investment (8.3%); training of graduate farmers (8.3%); linkages to local processors and produce off-takers (25%). Figure 12 more clearly compares the awareness rates elsewhere with those of E-farms. The differentials in favour of other sources may be due to the fact that E-farms began with the farmers barely 2 years before the survey.

Table 49: Distribution of farmers by awareness, sources of knowledge and assessment of relevance of ICT-enabled services

S/N	Service	%aware (n=24)	%aware from ICT org (n=24)	Relevance of service assessment (n=24)					
				NVR %	NR %	U %	R %	VR %	% NA
1	Market access for Farmers' products	33.3	8.3	0.0	0.0	0.0	8.3	25.0	66.7
2	Information to farmers on agricultural best practices	66.7	58.3	0.0	0.0	0.0	8.3	58.3	33.3
3	Access to extension services	75.0	66.7	0.0	0.0	0.0	16.7	50.0	33.3
4	Crowdfunding of capital for smallholder farmers	25.0	16.7	0.0	0.0	8.3	8.3	8.3	75.0
5	Platform for Peer to peer investment	25.0	8.3	0.0	0.0	0.0	8.3	16.7	75.0
6	Training of graduate farmers	25.0	8.3	0.0	0.0	0.0	8.3	16.7	75.0
7	Linkage of farmers to local processors and produce off-takers	41.7	25.0	0.0	0.0	0.0	16.7	33.3	50.0

Source: ICT users survey, 2019



Source: Calculated from Table 49

Fig 12: Awareness rates of services from E-Farms and from Elsewhere

The fish farmers were asked to rate each service as not very relevant (NVR), not relevant (NR), undecided (U), relevant (R), very relevant (VR) or not applicable (NA). The data in Table 50 show that no service was rated either NVR or NR. The rating of the services as R or VR was: market access for farmers' products (33.3%); information on agricultural best practices (66.6%); access to extension services (66.7%); crowdfunding of capital for smallholder farmers (16.6%); platform for peer to peer investment (25%); training of graduate farmers (25%); and linkages to local processors and produce off-takers (50%). In a heuristic sense, it appears that awareness was related to the rating of relevance.

Awareness, usage and understanding of ICT devices by farmers

Table 50 shows the distribution of farmers by awareness, usage and assessment of understanding of ICT devices among the respondents. At least 80% of the farmers indicated awareness of camera, mobile phone, short message service (SMS), smartphone app, email, point of sale terminal (POS) and automated teller machines (ATMs). Website was known to 75%, while voice recorder and call centre were known to 66.7% of the sample. Global positioning system (GPS), sensors, unstructured supplementary service data (USSD), cards and agent network were known to 50-58% of the respondents.

As for usage, only mobile phone and short message service (SMS) were indicated by at least 80% of the sample as being accessed from the Agri-tech. Camera, voice recorder, unstructured supplementary service data (USSD), smartphone app, and automated teller machines (ATMs) were indicated by 50-58% of the respondents as being accessed by them. As further shown, there were disparities between rates of awareness and usage of the ICT items by farmers by the Agri-tech. Again, the Agri-tech and farmers had partnered for less than 2 years prior to this survey; hence, these results showed that the Agri-tech was on the growth path.

The farmers were asked to rate each of the listed ICT items as not easily understood (NEU), not understood (NU), undecided (U), easily understood (EU), very easily understood (VEU) and not applicable (NA). The ICT item for which more than 80% of the respondents rated as EU or VEU was mobile phone. Short message service (SMS) was rated as EU or VEU by 75%, while camera, voice recorder and smartphone app were rated as EU or VEU by 50-58% of the respondents. A close look at all results in Table 49 suggests that ratings were linked to awareness of the ICT items.

Table 50: Distribution of farmers by awareness, usage and assessment of understanding of indicated ICT devices

S/N	ICT device	%aware (n=24)	% farmers served by ICT org (n=24)	Rating of ICT understanding (n=24)					
				NES %	NU %	U %	EU%	VEU %	NA
1	Global Positioning System (GPS)	50.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
2	Satellites	25.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3	Sensors	50.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4	Radio Frequency Identification (RFID) tags	25.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5	Camera	100.0	58.3	0.0	0.0	0.0	25.0	33.3	41.7
6	Voice recorder	66.7	50.0	0.0	0.0	0.0	25.0	25.0	50.0
7	Mobile phone	100.0	83.3	0.0	0.0	0.0	33.3	66.7	0.0
8	Short Message Service (SMS)	100.0	100.0		25.0		8.3	66.7	0.0
9	Unstructured Supplementary Service Data (USSD)	58.3	50.0	0.0	0.0	0.0	8.3	25.0	66.7
10	Call centre	66.7	41.7	0.0	0.0	0.0	8.3	33.3	58.3
11	Interactive voice Response (IVR)	16.7	0.0	0.0	0.0	0.0			100.0
12	Smartphone app	91.7	58.3	0.0	0.0	0.0	8.3	50.0	41.7
13	Webpage	75.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
14	Email	83.3	0.0	0.0	0.0	0.0	0.0	0.0	100.0
15	e-widgets	41.7	0.0	0.0	0.0	0.0	0.0	0.0	100.0
16	Machine learning	8.3	0.0	0.0	0.0	0.0	0.0	0.0	100.0
17	Artificial intelligence	16.7	0.0	0.0	0.0	0.0	0.0	0.0	100.0
18	Behavioural biometrics	25.0	0.0	0.0	0.0	8.3	0.0	0.0	91.7
19	Blockchain technology	0.0	0.0	0.0	0.0		0.0	0.0	100.0
20	Point of Sale Terminals (POS)	91.7	16.7	0.0	0.0	8.3		8.3	83.3
21	Automated Teller Machines (ATMs)	91.7	50.0	0.0	0.0	0.0	25.0	16.7	58.3
22	Cards	50.0	16.7	0.0	0.0	0.0	0.0	8.3	91.7
23	Agent network	58.3	25.0	0.0	0.0	0.0	8.3	16.7	75.0
24	Check out Application Programming Interface (APIs) for e-commerce	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

Source: ICT users survey, 2019

Capacity building and mode of service delivery by E-Farms

All respondents indicated being a member of a farmer organization. Table 51 shows the distribution of farmers by service-related training and mode of service delivery (individual or group). Training related to supplying information to farmers on agricultural best practices and access to extension services was received by 50% and 41.7% of the respondents, respectively. No farmer indicated additional training related to other listed services from the ICT Agri-tech. On how services were delivered, provision of information to farmers on agricultural best practices and access to extension services were channelled through groups, according to 58.3% and 50% of the respondents, respectively. The dominant trend was that services were rendered mainly to groups.

Table 51: Distribution of farmers by service-related training, group membership and mode of service delivery

S/N	Service	% trained on service (n=24)	How services are delivered (n=24)		
			%group	%individual	% NA
1	Market access for Farmers' products	0.0	0.0	0.0	100.0
2	Information to farmers on agricultural best practices	50.0	58.3	0.0	41.7
3	Access to extension services	41.7	50.0	0.0	50.0
4	Crowdfunding of capital for smallholder farmers	0.0	0.0	0.0	100.0
5	Platform for Peer to peer investment	0.0	0.0	0.0	100.0
6	Training of graduate farmers	0.0	0.0	0.0	100.0
7	Linkage of farmers to local processors and produce off-takers	0.0	0.0	0.0	100.0

Source: ICT users survey, 2019

Preliminary assessment of ICT impacts on fish farmers:

Table 52 shows the sources of household income. Consistent with Table 48, 91.9% of the respondents were fish farmers, while 58% were crop farmers, suggesting that partnership with E-farms did not make them abandon crop farming. The other suggested income sources were largely suppressed in percentage terms. In Table 53, the paired t-test shows that household income increased on the average, from NGN1,011,700.00 to NGN1,301,033.33 per annum, which respondents attributed to access to ICT-related services. The mean difference was significant at the 1% level.

Table 52: Distribution of farmers by sources of income

Income source	% receiving (n=24)
Sale of crops	58.3
Sale of livestock / fish (mainly fish)	91.9
Sale of other products e.g firewood, trees	8.3
Regular/salary employment	8.3
Agro-processing	0.0
Marketing / trading	0.0
Casual employment (agriculture)	0.0
Casual employment (non-agriculture)	0.0
Running own business	8.3
Remittances (e.g. money sent to respondent from relatives in the cities or from abroad)	0.0

Source: ICT users survey, 2019

Table 53: Simple Impact assessment of ICT on farmer income

Income variable	Sample estimate	Estimator
Total income per annum (NGN)	Value before ICT	1,011,700.00
	Value after ICT	1,301,033.33
	Sample size	24
	Mean difference	-289,333.33
	t-value	-2.62
	df	23
	2-tailed sig.	.015

Source: ICT users survey, 2019

Note: In constructing the paired t-test, the mean outcome 'after' was subtracted from the mean outcome 'before' ICT; hence, the negative t-values where the mean outcomes 'after' were higher.

Lessons learned from the ICT4Ag case studies

Some of the key lessons from the ICT4Ag case studies in Nigeria are:

- Strong emphasis on youth empowerment and participation in ICT-enabled services (Kitovu)
- Strong emphasis on farmer organizations / groups as platform for service delivery and capacity building / training (Kitovu; FarmCrowdy; ThriveAgric; E-farms)
- Emphasis mostly on data collection; other services include connection of smallholders to input sources, product processors and off-takers (Kitovu; Farmcrowdy)
- Data collection used mainly global positioning system (GPS), satellites, sensors, camera , mobile phone and smartphone app (Kitovu; Farmcrowdy)
- Reduction in post-harvest losses due to market linkages (Kitovu)
- Smallholders were poorly linked to credit facilities, while service providers had no own funds to on-lend (Kitovu)

- Changing government agricultural policies with successive administrations (Kitovu)
- Online partnership with produce buyers, smallholder farmers, investors, input sellers, insurance companies, investors, commercial farmers, and graduate farmers (Farmcrowdy)
- Poor access of farmers to smartphones, poor network connectivity in rural areas and language barrier (Farmcrowdy)
- Smallholder access to ICT-enabled linkages to product markets indicated by 9/10 farmers interviewed (ThriveAgric)
- Knowledge of ICT devices used for service delivery is high with 9/10 farmers interviewed (ThriveAgric)
- Preliminary evidence has shown income increase among small crop and aquaculture farmers arising from ICT services; however, further work will be needed to link the gains in income to specific services and /or ICT devices (ThriveAgric; E-farms)
- Preliminary evidence has shown output increase among small crop farmers arising from ICT services; however, further work will be needed to link the gains in output to area or yield or both; and to specific services and /or ICT devices (ThriveAgric)

Outlook for ICT4Ag in Nigeria

- The reach and benefits of D4AG will depend on access to mobile phones and connectivity by SHFs in the near future. The future is very bright for Nigeria in terms of mobile phone access, but more needs to be done in terms of connectivity.
- The cost of accessing data is expected to fall with time, due to competition among telecom operators and increase in public and private investments in the enabling inland optic fibre infrastructure. This will then stimulate the sluggish mobile money transactions to grow spirally to provide the much needed services to SHFs and other businesses along the various value chains. The private sector must lead the D4AG drive for sustainability in Nigeria. But government needs to step in to provide the fundamentals, which include upgrading small-scale infrastructure and last-mile infrastructures, both of which are ranked below the averages found elsewhere.
- Going by the count of solutions, Nigeria is one of the most active in terms of the D4AG activities. However, most of the ICT operators are small, with only Hello Tractor registering as many as 250,000 small farmers. FarmCrowdy reached some 7,000 farmers, while Crest Agro-processing project reached 5,000 registered farmers. An important factor retarding the scaling of solutions in Nigeria is the virtual absence of government in the aspect of inclusion of diverse smallholders. Since the present D4AG environment does not promote inclusiveness, ICT services tend to focus on profitable aspects of the value chain and large farms. For example, Hello Tractor offers tractor services using a network of extension agents, while AFEX uses Binkabi's blockchain technology to improve access to credit for farmers participating in grain storage across Nigeria. These D4AG solutions target big farms and specific activities along the value chains. This means that small and risk-prone farmers may be left behind unless there are policies to address the gap.
- Preliminary evidence has shown income increased among small crop and aquaculture farmers due to accessibility to ICT services; however, further work is needed to link the gains in income to specific services and /or ICT devices

- Preliminary evidence also showed that output increased among small crop farmers due to accessibility to ICT services; further work should be done to link the gains in output to area or yield or both; and to specific services and /or ICT devices.

Recommendations for policy

This study was designed to focus on the status of ICT infrastructure, the innovation environment for ICT, and the extent of ICT use in agriculture in Nigeria. Some of the recommendations for policy intervention from the findings are highlighted:

- There is general absence of government's nationwide direct investment in optic fibre cable infrastructure. Such investment in partnership with the private sector would reduce retain end Internet access cost. Moreover, the current privatization of the Nigerian power sector is more on paper than in practice. There is therefore an urgent need for a policy action to move from the present government dominance of the power value chain towards a private sector driven power market.
- The regulator of the communications sector (NCC) need to resist further acquisition of the smaller operators by the bigger ones, and facilitate an environment for the survival of smaller operators and/or ensure that acquired capacities by the bigger operators are put into full use.
- The limited access to the Internet among Nigerians seems to be explained more by the limited access to broadband services than the lack of phones. This also affirms the need for more public-private investment in fixed wireless infrastructure to enhance internet penetration.
- A close study of the communications policy environment in Nigeria shows that the country does not lack regulatory policies for a successful ICT innovation. Rather, what is lacking is the will to implement available policies. There is thus the need to streamline the policy documents, so that the implementing agencies can minimize inter-agency rivalry and end-user confusion.
- Numerous challenges have slowed growth of the telecom infrastructure in Nigeria. This leads to multiple costs, sundry revision of investment budgets, unnecessary repetition of infrastructure expenses and obstruction of services. There should be federal legislations that are binding on other levels of governance and targeted at curtailing these challenges.
- Both organizational and end-user case studies show the existence, awareness and relevance of ICT to various stages of agricultural value chain in Nigeria. The potential impact of ICT at the end-user level was also demonstrated. There is the need to boost ICT usage by addressing organizational and end-user constraints found through this study. Indeed, the regulator is not directly concerned with downstream or micro-level ICT applications, but proper upstream investments and regulations of service providers would positively impact on ICT Agri-techs and end-users.

References

African Business Online, 2019, Unlocking the potential of agricultural digitalization, https://africanbusinessmagazine.com/company-profile/african-green-revolution-forum-agrf/unlocking-the-potential-of-agricultural-digitalisation/

Agboje, Oboyerulu Edevbie , Simon Oluwatimilehin Adedoyin, Charles Uzoanya Ndujiuba. 2017. State of Optic fibre Networks for Internet Broadband Penetration in Nigeria - A Review, International Journal of Optoelectronic Engineering 2017, 7(1): 1-12

AgroNigeria , 2019, Cellulant Agrikore takes giant stride in Africa's Agritech market, https://agronigeria.ng/cellulant-agrikore-takes-giant-stride-in-africas-agritech-market/

Akinsola, B. (2016). "MTN pays $96 million to NCC for 6GHz licence". Available at: http://naija247news.com/2016/06/29/mtn-pays-96-million-to-ncc-for-6ghz-licence/ (accessed December 2017)

Association for Progressive Communications (APC). 2010. "Spectrum for Development: Nigeria". Available at: www.apc.org/sites/default/files/countries/factsheet%20nigeria_eng.pdf (accessed December 2017).