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The ICT Health Checkup Tool: Assessing Connectivity of the National Agriculture Research System (NARS)

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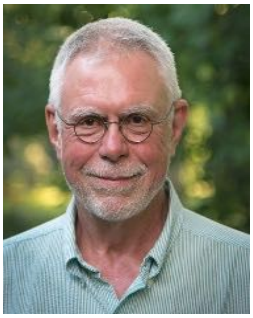

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ABSTRACT

In the global knowledge economy, connectivity is the oxygen for any research and development institutions such as those within the National Agriculture Research System (NARS). The need to empower the NARS to assume research and development leadership requires superior information communication technology (ICT) infrastructure. Specifically, the manuscript addresses two new research questions: 1) what is the state, both quantitatively and qualitatively, of ICT at a NARS institution, and 2) what should a tool look like whereby NARS network managers can on their own benchmark and monitor the state of their ICT systems. The research team employs the case study method to measure the state of ICT connectivity for the Savanna Agricultural Research Institute (SARI), a leading station within the Council for Scientific and Industrial Research of Ghana. Additionally, the research team develops, describes, and applies a new assessment tool, the ICT Health Checkup, which NARS and higher education institutions can utilize. This research fills a void in the ICT for development literature, which to date provides no guidance for research institutions in the developing world as to how they are to access the connectivity they need to be able to provide scientific leadership at the national, regional, and international level. The results quantify the gap between the needs of the researchers, support staff, and administration and the available service. Additionally, the ICT Health Checkup Tool not only shows NARS leadership their connectivity gaps, but also provides specific and measurable benchmarks of the physical infrastructure, intranet services, and capacity of the ICT staff. Finally, the case study provides important insights as to the way forward. The case motivates the underlying economies of scale associated with ICT systems, and the need for NARS to leave the current model of individual contracts with telecom providers. Collaborating with like institutions aggregates demand, which in turn lowers the costs per unit of bandwidth. In this vein, the case study shows the value of the relatively new National Research and Education (NREN) model to bring much needed connectivity to the region's agricultural researchers.

Key words: Information and Communication Technology, connectivity, Ghana, National Research and Education Network

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INTRODUCTION

The poor state of connectivity for our research partners in Ghana, as well as many other NARS locations throughout SSA motivates this research. The Chronicle of Higher Education concluded that internet connectivity "…is the air we breathe… everything we do now has tech in it" [1]. Therefore, connectivity is the oxygen for any research and development institutions such as those within sub-Saharan Africa's (SSA's) National Agriculture Research System (NARS) that seek to be research and development leaders.

Local research partners' ability to become empowered and drive the R&D agenda, as well as fully leverage donor dollars for sustained outcomes, is directly a function of their level of information and communication technology (ICT) connectivity. In addition to connectivity problems, those responsible for leading NARS institutions find themselves without a reliable connectivity assessment and planning tool. Formally understanding the state of ICT connectivity at an institution becomes the first step in the process to provide the African research community the "oxygen" it needs to participate actively in both national research and development, as well as the world scientific, community.

This manuscript, the first of its kind, addresses these problems by producing a detailed case study measuring and evaluating the state of internet connectivity for the Savanna Agricultural Research Institute (SARI), a leading station with the Council for Scientific and Industrial Research of Ghana. The manuscript reflects research on the state of ICT connectivity, and in doing so creates an assessment tool, the ICT Health Checkup, for NARS administrators to measure and benchmark the connectivity of their institutions.

For the past twenty years, there has been a growing recognition throughout SSA of the critical importance of making better use of ICTs to advance both the agricultural sector in general, and NARS institutions in particular. In April 1999, the Executive Secretary of the NARS Secretariat reported to the Global Forum on Agricultural Research (GFAR) that SSA faced mounting pressures on multiple fronts due to challenges of increasing hunger, poverty, and population growth [2]. He added that all relevant regional strategic studies confirm the importance for all development entities, including all NARS institutions, as well as the general public, to gain better access to ICTs if they were to be successful in the new environment of agricultural research for development [2]. To date no such tool exists, nor is there any information as to the level and quality of institutional connectivity.

Five years later, a senior analyst for GFAR, Ajit Maru, reported that despite the widespread use of personal computers and ubiquitous Internet connectivity throughout much of SSA, many NARS institutions still faced significant gaps and weaknesses in their ICT infrastructure including poor Internet connectivity and inadequate staff skills for effectively using and managing ICT [3]. Maru concluded that most of these weaknesses stemmed primarily from a lack of capital investment in ICT in the NARS institutions.

In 2012, the World Bank reinforced and expanded these themes in a 164-page report titled *"The Transformational Use of Information and Communication Technologies in*

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Africa" [4]. The report noted the growing potential for ICT tools to help tackle some of the agriculture's major challenges. The World Bank called for increased connectivity to support research and education, noting that the emergence of NRENs in Africa over the past ten years had shown great promise.

In 2016, Michael Foley, the former lead Distance Learning Specialist (1997-2015) at the World Bank, authored an extensive report on "The Role and Status of National Research and Education Networks (NRENs) in Africa" [5]. He motivates the case for NRENs in SSA, describes the early history of creating NRENs in SSA, and presents the challenges/opportunities that those NRENs (and the agencies that support them) face moving forward, both financially and operationally.

Recently, the National Research and Education Network (NREN) has emerged aggregating demand and started to bring internet connectivity to the NARS and institutions of higher learning in SSA. There have been significant improvements in ICT connectivity for research institutions in some leading SSA countries, such as Kenya and South Africa [4]. Unfortunately, Kenya member institutions of KENET face bandwidth charges of $160 per Mbps [6], which is significantly higher than peer institutions in North America and Europe, and as a result constrains integration of ICT into the daily systems of the research community.

The NREN system presents great potential to help NARS institutions, that in the past sought connectivity as isolated buyers. To this end, the ICT Health Checkup will help NRENS and their clients, the NARS, formally benchmark the connectivity level and infrastructure quality and capacity on site.

MATERIALS AND METHODS

Data Collection and the Case Study Method

At its core, internet and communication technology analysis lends itself well to traditional scientific research design. Formal engineering relationships are known and quantifiable, which allows for a central role for standard statistical analyses of the system under study and for involving set routines and heuristics to quantify deviation from norms [7, 8, 9].

However, developing country settings significantly differ. Poor ICT connectivity presents additional complex social, political, cultural, and economic factors. These in turn contribute to system failure, in addition to the standard engineering aspects [10, 11].

To date little work addresses the scope, causes, performance, and remediation of the underlying ICT infrastructure affecting the education and research system of sub-Saharan Africa. The case study method has utility for collecting primary data in the field because within a complex developing world environment, current theory, empirical findings, and engineering standards all arise from a developed, not a developing, nation context. The local context and actors within the case allow research to properly adjust analyses to correctly: 1) measure the adequacy of current ICT connectivity, 2) identify

the critical control points leading to poor system performance in SSA, and 3) put in place an appropriate corrective plan for the setting and budget.

Similar to Tibben [10], the research team had little control or real understanding at the onset of this research as to the many actors and variables involved in developing country ICT systems. With guidance from Ragin and Becker [12], the case method serves the research process well as the literature provides little guidance as to the structure of the causal processes that result in poor connectivity. The case study method informs the building of the assessment tool, which in turn feeds back to shed light on the causal processes and system underlying the connectivity problem within a developing country setting.

The data triangulation strategy involved: 1) two focus groups; 2) 46 key informant interviews; 3) primary data collection and measurement on site; 4) a two week on-site visit; 5) secondary data collection about the state of the national (Ghana) ICT infrastructure; 6) a literature review on ICT connectivity in Africa; and 7) ongoing, follow-up communications with a number of the key informants.

This case study emerges from a six-year research partnership between the Soybean Innovation Lab and the Savanna Agricultural Research Institute. Over that time, the two organizations actively collaborated at the senior administration and research staff level, operated a 2-hectare research farm, conducted numerous field days and trainings, and underwent countless webinars and conference calls where SARI colleagues could not connect. These experiences sensitized the authors to the breadth and severity of the connectivity problem from a users' perspective. These broad set of experiences too provide some measure of validation during the data collection phase.

The research team conducted interviews and focus groups with 46 actors familiar with the issue of ICT connectivity within a developing country context (Table 1). The 46 represent nine different types of organizations. The first group was university network managers at the University of Illinois, the University for Development Studies (Ghana), and the University of Ghana who comprised 28% of all interviews and 68% of the technical interviews. A second set of interviews took place with four IT specialists from Ghana, Mozambique, and Zimbabwe.

Much time, on two visits, involved interaction with the 9-member SARI ICT team comprised of the two technical staff members who are responsible for managing the network, one communications specialist, and six researchers. Additionally, the team interviewed SIL (0 technical and 10 researchers) and other international researchers (0 technical and 5 researchers) familiar with both the situation at SARI and connectivity in general throughout the NARS system.

The two focus groups centered on specific questions about user experiences operating under the current connectivity environment, and ideas to improve the current state. The focus groups involving administrative and research personnel shed important light on role ICT played in their day to-day routines as intellectual leaders in their fields, costs of delivery, and the history of ICT at SARI.

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Independent primary data included all direct measurements and evaluation of connectivity through a direct assessment of SARI's system, hardware, software, and maintenance procedures. Full access and complete collaboration between SARI administrators, ICT personnel, and the research team eliminated selectivity bias from the data collection process. The research team had full access to the network. They verified makes, models, and installation/repair histories for key components. Consistent with Pfigu [13], and interviews with other ICT providers in the region (telecoms) and the University for Development Studies, located on an adjacent campus validated the primary data.

The ICT Health Checkup

The ICT Health Checkup mirrors the sort of general physical health screening that takes place when individuals go to their physician on a regular basis to evaluate their overall health condition and to identify areas for increased attention. The ICT Health Checkup serves a number of purposes. First, just as it is desirable for an individual to have a good "score" on their blood pressure tests, blood sugar levels, and others, the same is true of the component "test results" of a NARS institution's ICT Health Checkup assessment.

The ICT Health Checkup also serves as a self-guided discovery tool and gap analysis aid for the development of a plan of work for NARS ICT personnel. The Checkup clearly identifies missing elements and performance targets. The tool makes explicit what may be implicit, so is helpful for problem solving and communicating with outside technical service providers.

The ICT Health Checkup also acts as a benchmarking program to measure performance over time, and inter-temporally evaluate module improvements. Finally, as mentioned earlier, researchers can aggregate the structured data from the Health Checkup to conduct more formal analyses about the state of ICT throughout the agricultural research and education system of SSA.

Measurable and quantifiable data are essential for making sound management and budgetary decisions. The ICT Health Checkup design reflects this with its emphasis on precise measurement. Where strict per-unit measurement is not appropriate or possible, the ICT Health Checkup asks the person gathering the data to indicate the current status of a desired service, procedure, or set of necessary infrastructural equipment, for example, is it operational? Or is it not operational? Is it planned but not yet implemented?

The ICT Health Checkup comprises four tabbed worksheets in an Excel workbook file. The tool uses a number of embedded calculations and criteria that employ established standards for ICT provisioning. Approximately 99% of all data entry on the four worksheets will take place in Column D on each worksheet. Internet technology managers input data into all cells in the "D" column that have a pencil icon displayed to the immediate left of that cell.

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Some cells also have an icon of a horizontal traffic signal to their immediate left.

This indicates evaluation results associated with the input raw data. A green cell indicates all is in order. Yellow indicates caution, and red signifies a serious problem. An "accomplished" ICT implementation plan occurs when all the color-coded cells next to the traffic signal icon turn green.

Blue- colored cells in Column D display calculated results (primarily on the bandwidth worksheet). Grey-colored cells in Column D allow users to input detailed supporting information on the Infrastructure and the Intranet worksheets.

The ICT Health Checkup structure involves four critically important components that are each essential if a NARS institution is to have high-bandwidth internet connectivity and a secure, smoothly operating suite of reliable intranet services for researchers to use in their daily work. Those four areas are: Connectivity/Bandwidth, Physical Infrastructure, Intranet Services, & Professional ICT Staff. Each component is essential for a smoothly running, fully functioning ICT operation. At the head of the list comes the task of examining the institution's connectivity/bandwidth. If a research institution does not have sufficient connectivity, then little else matters until that improves.

Connectivity/Bandwidth

The first tab in the workbook concerns connectivity and bandwidth (Figure 1). It is important to begin by determining how many senior researchers, top administrators, and lower-level support staff work at the institution, and then differentiating each position ICT needs and priority level. Senior research and administration staff, including the ICT professional support staff, must be able to not only easily access large files online and share data with colleagues, but also participate in real-time video-based conferences with peers in other parts of the world. Network managers will establish a minimal connectivity level for the institution by assessing then summing the functional and data needs for each user.

It is also important to establish if the main location for the NARS institution (a) already has a fiber- based infrastructure providing connectivity to the internet and (b) if it does, is the connection an uninterrupted, all-fiber pathway all the way back to the backbone?

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ICT Health Checkup (insert NARS name here - in the Connectivity Tab) Connectivity/Bandwidth			
Primary location:			
Number of senior researchers & administrators at this location who need hi performance bandwidth			← Connectivity D-6
Number of staff at this location who could get by with lower performance bandwidth			← Connectivity D-7
Number of rooms where video conferencing capability is needed (such as GoToMeeting)			← Connectivity D-8
total number of staff at this location		0.00	← Connectivity D-9
How much bandwidth is the current ISP contracted to deliver to the main location? **(in Mbps)**			← Connectivity D-10
What is the name of the current ISP?			← Connectivity D-11
Have you contacted the National Research Education Network (NREN) in your country? **(select from drop down options in D12)**			← Connectivity D-12
Calculated minimum bandwidth needs for this location **(in Mbps)**		0.00	← Connectivity D-13
Surplus or Deficit for main location? **(in Mbps)**		0.00	← Connectivity D-14
What would be the minimum bandwidth to provide DESKTOP video conferencing for all senior staff members? **(in Mbps)**		0.00	← Connectivity D-16
take measurement of download speed using SpeedTest - when logged in as a "high-performance" user **(in Kbps)**			← Connectivity D-18
Do the measured download speeds meet minimum acceptable standards?			← Connectivity D-19
Does the NARS institution already have a fiber infrastructure that is connected to the internet? **(select from drop down options in D21)**			← Connectivity D-21
If so, is there an uninterrupted, ALL-FIBER PATHWAY all the way back to the backbone? **(select from drop down options in D22)**			← Connectivity D-22
Are there any remote locations that need to be part of this network thru a managed VPN? If so, how many?			← Connectivity D-24
Remote Location #1:			
Number of senior researchers & administrators at this location who need hi performance bandwidth			← Connectivity D-27
Number of staff at remote location #1 who could get by with lower performance bandwidth			← Connectivity D-28
Number of rooms where video conferencing capability is needed (such as GoToMeeting)			← Connectivity D-29
Total number of staff at remote location #1:		0	← Connectivity D-30
How much bandwidth is the current ISP contracted to deliver to this remote location? **(in Mbps)**			← Connectivity D-31
What is the name of the current ISP?			← Connectivity D-32
Calculated minimum bandwidth needs for this location **(in Mbps)**		0.00	← Connectivity D-33
Surplus or Deficit for remote location #1? **(in Mbps)**		0.000	← Connectivity D-34
take measurements of download/upload speeds - when logged in as a "high-performance" user. **(in Kbps)**			← Connectivity D-35
Do the measured download speeds meet minimum acceptable standards?			← Connectivity D-36
What percent of time does the site have dependable electricity? ***(select from drop down options in D34)***			← Connectivity D-37
Remote Location #2:			
Number of senior researchers & administrators at this location who need hi performance bandwidth			← Connectivity D-40
Number of staff at remote location #2 who could get by with lower performance bandwidth			← Connectivity D-41
Number of rooms where video conferencing capability is needed (such as GoToMeeting)			← Connectivity D-42
Total number of staff at remote location #2:		0	← Connectivity D-43
How much bandwidth is the current ISP contracted to deliver to this remote location? **(in Mbps)**			← Connectivity D-44
What is the name of the current ISP?			← Connectivity D-45
Calculated minimum bandwidth needs for this location **(in Mbps)**		0.00	← Connectivity D-46
Surplus or Deficit for remote location #2? **(in Mbps)**		0.00	← Connectivity D-47
take measurements of download/upload speeds - when logged in as a "high-performance" user. **(in Kbps)**			← Connectivity D-48
Do the measured download speeds meet minimum acceptable standards?			← Connectivity D-49
What percent of time does the site have dependable electricity? ***(select from drop down options in D47)***			← Connectivity D-50
Total bandwidth contracted for both main location and all remote locations.		0.00	← Connectivity D-52
Total per month costs of current bandwidth from contracted ISP (in US$)			← Connectivity D-53
Total Bandwidth needs for main location and all remote locations. **(in Mbps)**		0.00	← Connectivity D-54
Surplus or Deficit for entire system including any remote stations? **(in Mbps)**		0.00	← Connectivity D-55
If a bid has been obtained, what are the additional costs (USD$) to increase bandwidth to meet standard levels for all locations?			← Connectivity D-57
Total costs **with this vendor** to obtain standard bandwidth levels for all locations:		$ -	← Connectivity D-58

Figure 1. A Screenshot of the Connectivity/Bandwidth Worksheet

It is essential for the answers to both of these questions to be yes. Just as a chain is only as strong as its weakest link, a network that does not have an uninterrupted and all-fiber pathway back to the backbone, will only be able to transmit data at the speed of its slowest link.

At the absolute minimum, there must be at least one location at the main institution where senior level personnel can use video-conferencing tools. For example, the technical staff at both GoToMeeting and Skype advise that in order to participate in trouble-free video conferences on their platforms, that users should have a guaranteed 4Mbps downward connection from the Internet (upload requirements are less). Therefore, in the ICT Health Checkup, there is a question concerning the number of rooms that have dedicated video conferencing capabilities. The number that is input into that field multiplied by 4,000 accounts for the bandwidth required for each videoconferencing site as expressed in Kbps. This total becomes one component of the institution's total bandwidth needs.

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Given that most NARS institutions have extremely limited connectivity, it is reasonable to start out with a minimum bandwidth allocation for the institution's senior staff of 512 Kbps and a minimum allocation of 128 Kbps for support staff members. Additional allocations will require additional levels of connectivity for data-intensive activities such as individual video conferencing access or participating in remote simulations on a super-computer. Research counterparts in developed countries have full access to video conferencing at their desktops. Such an expectation means giving all researchers and administrators a 4Mbps bandwidth allocation. Obviously, a higher bandwidth allocation for senior level employees would benefit all tasks carried out by them over both the internet and the institution's intranet.

There are important questions concerning the specific needs of the remote stations at SARI, located in Wa and Manga as well, which increases the functional level of connectivity. The Savanna Agricultural Research Institute for example, needs to maintain a managed Virtual Private Network (VPN) to link all three campuses.

Cost Factors

The Connectivity/Bandwidth worksheet requires the person inputting the data to provide the per month costs of current bandwidth in US dollars. The color-coded bandwidth deficit will show in a calculated field, as will the cost per unit, when the levels are less than the minimum requirements. The ICT health Checkup allows technical managers to input the various details of alternative configurations and vendor bids to explore the effects on; addressing the deficit, the costs per unit of connectivity, and total costs.

Physical Infrastructure Questions

The second area of the ICT Health Checkup assesses the core physical infrastructure (Figure 2).

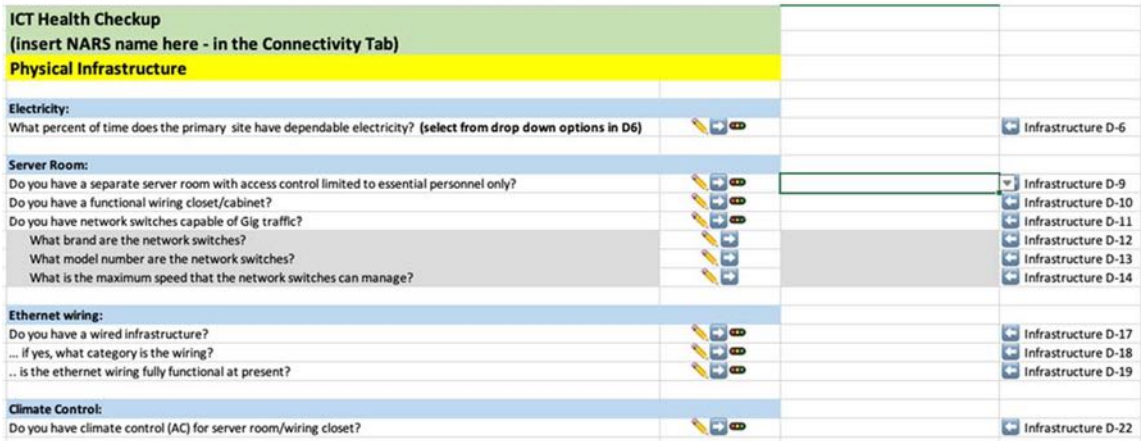

Figure 2. Screenshot of the Physical Infrastructure Worksheet

Assuming sufficient connectivity exists, the institution needs to maintain the infrastructure elements to interconnect with the internet dependably and consistently maintain core operations of a dependable suite of intranet services. The specific infrastructural prerequisites that a NARS institution must have to support its network include:

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- A dependable source of constant electricity. If it is below 95% reliable, then some sort of backup electricity supply such as a generator is essential.
- A separate server room that has controlled access for security and 24-hour climate control to maximize the life of the equipment.
- A properly functioning network switch, which is essential piece of complex equipment that connects other computing devices together and manages the flow of all data traffic across the network at gigabit speeds.
- An up-to-date Ethernet wiring infrastructure for the Local Area Network.
    - Ethernet cabling connects the main server to all of the wireless access points (WAPs), if the institution provides wireless networking to its users.
    - The institution may also provide direct hard-wired connections to computer workstations, printers, and other shared devices.
    - "Category 6 ethernet," which is capable of 1 Gbps transmission, provides the most up-to-date technology, and is the most common among recent installations.
    - In general, hard-wired Ethernet connections are faster and more reliable than wireless connections.

Intranet Services

The third area of the ICT Health Checkup involves a long set of questions regarding the current (or planned) state of desirable intranet service offerings that are available at the NARS institution for researchers and other staff members (Figure 3). The focus here turns to identifying the state of, and goals for, the internal network at the organization that directly services each of the users (the intranet services).

Critical areas for examination are:

- The quality and capacity of the central network server.
- The ability of the account management software to:
    - establish and manage user accounts on the network,
    - allocate specific bandwidth levels to users based on their position and needs,
    - monitor staff network usage patterns.
- Security issues, including procedures for virus and malware scanning, data protection protocols, maintenance of an active firewall, routine backups of applications and user data, procedures for maintaining up-to-date patches on all applications and operating systems, and maintenance of written policies for use of networked resources.

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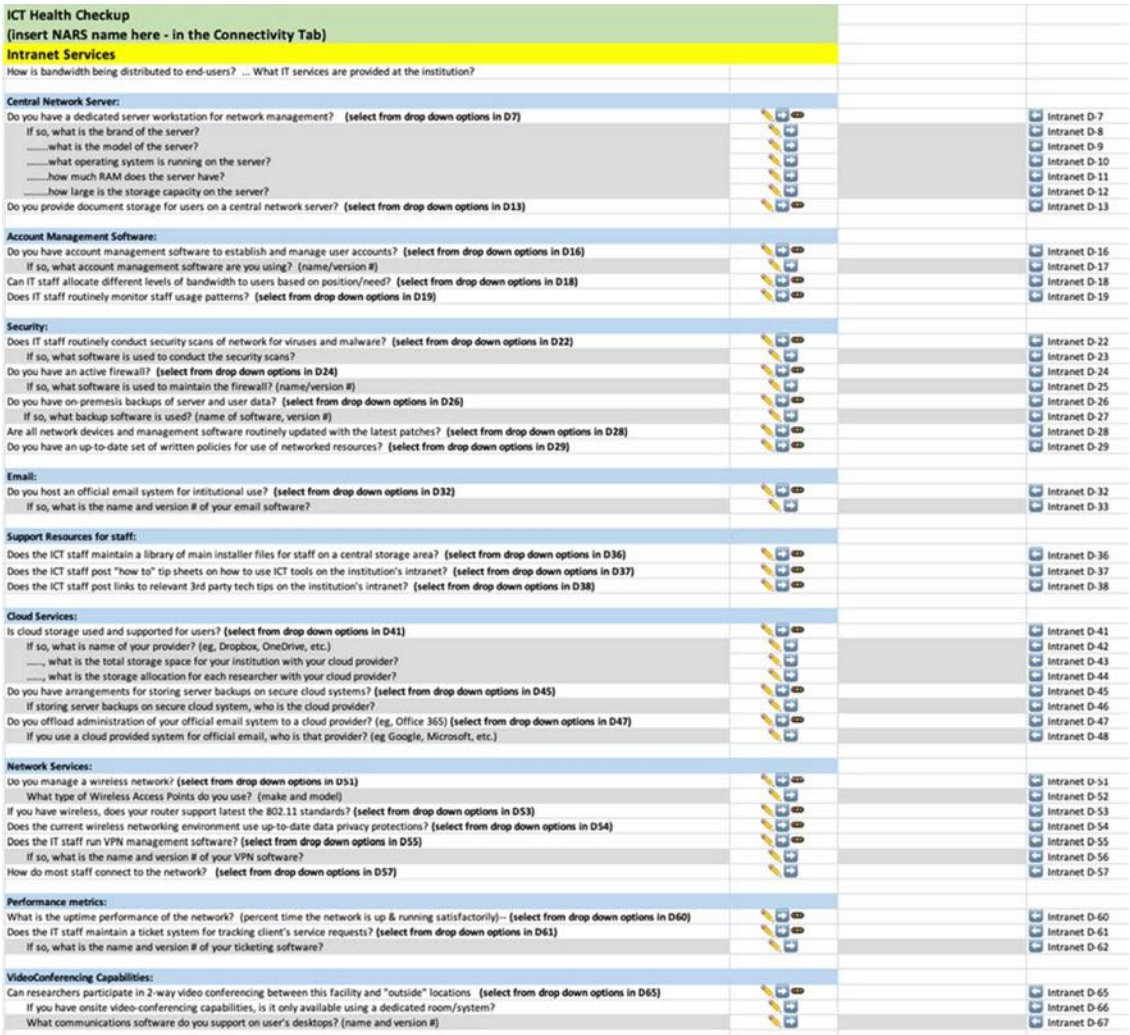

ICT Health Checkup (insert NARS name here - in the Connectivity Tab) Intranet Services			
How is bandwidth being distributed to end-users? ... What IT services are provided at the institution?			
Central Network Server:			
Do you have a dedicated server workstation for network management? (select from drop down options in D7)			Intranet D-7
If so, what is the brand of the server?			Intranet D-8
.....what is the model of the server?			Intranet D-9
.....what operating system is running on the server?			Intranet D-10
.....how much RAM does the server have?			Intranet D-11
.....how large is the storage capacity on the server?			Intranet D-12
Do you provide document storage for users on a central network server? (select from drop down options in D13)			Intranet D-13
Account Management Software:			
Do you have account management software to establish and manage user accounts? (select from drop down options in D16)			Intranet D-16
If so, what account management software are you using? (name/version #)			Intranet D-17
Can IT staff allocate different levels of bandwidth to users based on position/need? (select from drop down options in D18)			Intranet D-18
Does IT staff routinely monitor staff usage patterns? (select from drop down options in D19)			Intranet D-19
Security:			
Does IT staff routinely conduct security scans of network for viruses and malware? (select from drop down options in D22)			Intranet D-22
If so, what software is used to conduct the security scans?			Intranet D-23
Do you have an active firewall? (select from drop down options in D24)			Intranet D-24
If so, what software is used to maintain the firewall? (name/version #)			Intranet D-25
Do you have on-premesis backups of server and user data? (select from drop down options in D26)			Intranet D-26
If so, what backup software is used? (name of software, version #)			Intranet D-27
Are all network devices and management software routinely updated with the latest patches? (select from drop down options in D28)			Intranet D-28
Do you have an up-to-date set of written policies for use of networked resources? (select from drop down options in D29)			Intranet D-29
Email:			
Do you host an official email system for intitutional use? (select from drop down options in D32)			Intranet D-32
If so, what is the name and version # of your email software?			Intranet D-33
Support Resources for staff:			
Does the ICT staff maintain a library of main installer files for staff on a central storage area? (select from drop down options in D36)			Intranet D-36
Does the ICT staff post "how to" tip sheets on how to use ICT tools on the institution's intranet? (select from drop down options in D37)			Intranet D-37
Does the ICT staff post links to relevant 3rd party tech tips on the institution's intranet? (select from drop down options in D38)			Intranet D-38
Cloud Services:			
Is cloud storage used and supported for users? (select from drop down options in D41)			Intranet D-41
If so, what is name of your provider? (eg, Dropbox, OneDrive, etc.)			Intranet D-42
....., what is the total storage space for your institution with your cloud provider?			Intranet D-43
....., what is the storage allocation for each researcher with your cloud provider?			Intranet D-44
Do you have arrangements for storing server backups on secure cloud systems? (select from drop down options in D45)			Intranet D-45
If storing server backups on secure cloud system, who is the cloud provider?			Intranet D-46
Do you offload administration of your official email system to a cloud provider? (eg, Office 365) (select from drop down options in D47)			Intranet D-47
If you use a cloud provided system for official email, who is that provider? (eg Google, Microsoft, etc.)			Intranet D-48
Network Services:			
Do you manage a wireless network? (select from drop down options in D51)			Intranet D-51
What type of Wireless Access Points do you use? (make and model)			Intranet D-52
If you have wireless, does your router support latest the 802.11 standards? (select from drop down options in D53)			Intranet D-53
Does the current wireless networking environment use up-to-date data privacy protections? (select from drop down options in D54)			Intranet D-54
Does the IT staff run VPN management software? (select from drop down options in D55)			Intranet D-55
If so, what is the name and version # of your VPN software?			Intranet D-56
How do most staff connect to the network? (select from drop down options in D57)			Intranet D-57
Performance metrics:			
What is the uptime performance of the network? (percent time the network is up & running satisfactorily)-- (select from drop down options in D60)			Intranet D-60
Does the IT staff maintain a ticket system for tracking client's service requests? (select from drop down options in D61)			Intranet D-61
If so, what is the name and version # of your ticketing software?			Intranet D-62
VideoConferencing Capabilities:			
Can researchers participate in 2-way video conferencing between this facility and "outside" locations (select from drop down options in D65)			Intranet D-65
If you have onsite video-conferencing capabilities, is it only available using a dedicated room/system?			Intranet D-66
What communications software do you support on user's desktops? (name and version #)			Intranet D-67

Figure 3. Screenshot of Intranet Services Worksheet

- Email issues. For example:
  - does the institution have an official email system (whether on-site or off- loaded) and require users to use it while conducting official business?
  - does the institution operate its own email server, or is that operation off-loaded to a cloud service provider, such as Microsoft's Office 365?
- Support services. For example:
  - do the ICT professional staff members maintain an up-to-date library of main installer files for staff in a central storage area?
  - do they post "tip sheets" for users on how to use ICT tools?
  - do they share appropriate 3rd party tech tips with users on the intranet?

- Cloud services. For example:
    - is cloud-based storage provisioned for users?
        - If so, what is the allocation?
    - does the ICT professional staff use the cloud for secure backup services?
- Network services. For example:
    - does the institution provide wireless access?
    - does it meet the latest security standards?
    - what is the transmission speed?
    - does the institution use a virtual private network (VPN) to link external research facilities together with the main institution?
- Performance metrics. For example:
    - what is the uptime performance of the network?
    - do the ICT professional staff maintain a ticketing system to track user requests?
- Video-conferencing facilities. For example:
    - can researchers use video conferencing equipment to communicate with colleagues and peers at other locations?
    - is that service only available at a central location/facility?
        - Or, can researchers conduct video-conferences from their desktop?

Professional ICT Staff

The fourth component of the ICT Health Checkup focuses on queries related to the professional ICT staff (Figure 4).

For each member of the ICT professional staff, the Checkup asks:

- about their formal educational background.
    - For example, did s/he graduate from the university?
        - If so, what was the major field of study?

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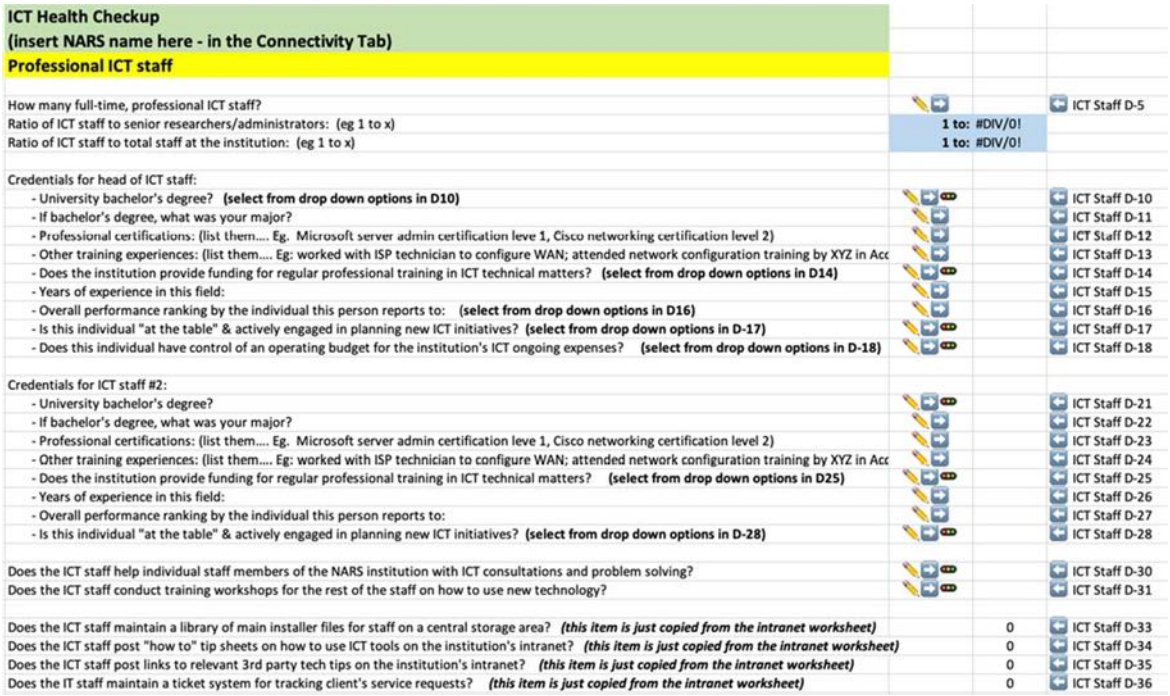

ICT Health Checkup			
(insert NARS name here - in the Connectivity Tab)			
Professional ICT staff			
How many full-time, professional ICT staff?			ICT Staff D-5
Ratio of ICT staff to senior researchers/administrators: (eg 1 to x)	1 to: #DIV/0!		
Ratio of ICT staff to total staff at the institution: (eg 1 to x)	1 to: #DIV/0!		
Credentials for head of ICT staff:			
- University bachelor's degree? **(select from drop down options in D10)**			ICT Staff D-10
- If bachelor's degree, what was your major?			ICT Staff D-11
- Professional certifications: (list them.... Eg. Microsoft server admin certification leve 1, Cisco networking certification level 2)			ICT Staff D-12
- Other training experiences: (list them.... Eg: worked with ISP technician to configure WAN; attended network configuration training by XYZ in Acc			ICT Staff D-13
- Does the institution provide funding for regular professional training in ICT technical matters? **(select from drop down options in D14)**			ICT Staff D-14
- Years of experience in this field:			ICT Staff D-15
- Overall performance ranking by the individual this person reports to: **(select from drop down options in D16)**			ICT Staff D-16
- Is this individual "at the table" & actively engaged in planning new ICT initiatives? **(select from drop down options in D-17)**			ICT Staff D-17
- Does this individual have control of an operating budget for the institution's ICT ongoing expenses? **(select from drop down options in D-18)**			ICT Staff D-18
Credentials for ICT staff #2:			
- University bachelor's degree?			ICT Staff D-21
- If bachelor's degree, what was your major?			ICT Staff D-22
- Professional certifications: (list them.... Eg. Microsoft server admin certification leve 1, Cisco networking certification level 2)			ICT Staff D-23
- Other training experiences: (list them.... Eg: worked with ISP technician to configure WAN; attended network configuration training by XYZ in Acc			ICT Staff D-24
- Does the institution provide funding for regular professional training in ICT technical matters? **(select from drop down options in D25)**			ICT Staff D-25
- Years of experience in this field:			ICT Staff D-26
- Overall performance ranking by the individual this person reports to:			ICT Staff D-27
- Is this individual "at the table" & actively engaged in planning new ICT initiatives? **(select from drop down options in D-28)**			ICT Staff D-28
Does the ICT staff help individual staff members of the NARS institution with ICT consultations and problem solving?			ICT Staff D-30
Does the ICT staff conduct training workshops for the rest of the staff on how to use new technology?			ICT Staff D-31
Does the ICT staff maintain a library of main installer files for staff on a central storage area? ***(this item is just copied from the intranet worksheet)***		0	ICT Staff D-33
Does the ICT staff post "how to" tip sheets on how to use ICT tools on the institution's intranet? ***(this item is just copied from the intranet worksheet)***		0	ICT Staff D-34
Does the ICT staff post links to relevant 3rd party tech tips on the institution's intranet? ***(this item is just copied from the intranet worksheet)***		0	ICT Staff D-35
Does the IT staff maintain a ticket system for tracking client's service requests? ***(this item is just copied from the intranet worksheet)***		0	ICT Staff D-36

Figure 4. Screenshot of Professional ICT Staff Worksheet

It also is important to know the number of professional certificates and engagement in other ICT training experiences. The Checkup asks as well whether the institution supports its ICT professional staff by regularly providing funding for training and release time for professional improvement. This is particularly important in a rapidly changing environment like ICT. The Checkup also asks the number of years of professional experience and how their supervisor ranks their performance. The Checkup also seeks to know whether the individual is "at the table" and actively working with administrative leadership in planning new ICT initiatives. In a similar vein, the Checkup asks if the head of the ICT group has control of the operating budget for the institution's ongoing ICT expenses. Finally, the Checkup asks if the ICT staff helps researchers, administrators, and other staff members with ICT consultations and problem solving. For example, do they conduct training workshops for the rest of the staff on how to use new technologies?

RESULTS AND DISCUSSION

In 2017, USAID-Ghana issued a report stating SARI's ICT needs were great and would require a $130,430 one-time expenditure and $66,500 of recurring annual charges [13]. The report outlined significant deficiencies in SARI's physical infrastructure, server room, server equipment and software, power backup systems, security equipment and procedures, data backup equipment/protocols, disaster recovery preparedness, networking, Internet and email access, and training. Interestingly though, the report recommended that SARI's bandwidth be upgraded from a 2Mb shared connection to a 10Mb shared connection at the Nyankpala station. The recommendation also included obtaining service from a commercial telecom ISP. The report also recommended that the remote stations of Manga and Wa receive 4Mb connections [13].

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By any standard of individual usage rates, such a recommendation was extremely low. The total bandwidth for SARI must service 140 people at Nyankpala (40 of whom are senior researchers or administrators) plus 15 people at Manga and 10 at Wa. Two separate personal communications confirm that the bandwidth recommendation does not result from a technical assessment of need. It reflects financial constraints facing both SARI's capital and operating resources, and USAID's donor funds, as well as, the high cost per unit of telecom connectivity [14a and 14b]. These findings are consistent with earlier results that part of the ICT weaknesses at NARS institutions stem primarily from a lack of capital investment in ICT by those same institutions [3, 6].

These findings point to a critical theme when meeting the ICT needs of public research and education institutions, whether in the US or in Ghana. The cost per user is expensive when priced at the retail level offered by telecom ISP providers. National Agricultural Research System administrators need to respect the significant economies of scale associated with ICT provision. It is not financially feasible for an individual institution like SARI to address its ICT as an independent buyer of bandwidth in the marketplace. Thus, some form of aggregation strategy involving wholesale procurement of bandwidth will be key features of SARI's ICT solution.

The Savanna Agricultural Research Institute successfully replaced its earlier 2Mbps shared connection provided by a telecom provider, Vodaphone- Ghana that served only the Nyankpala station. The new contract in 2018 with another telecom provider, MTN, delivers a shared 10Mb connection to Nyankpala and a 4Mbps connection to both Manga and Wa for a total of 18 Mb. The cost of the old 2Mbps service had been $802 per month. The upgrade to an 18Mbps package was $4,112 per month.

For reference, homeowners in the United States can obtain a 20Mbps download package that supports two users at a cost of $20-$25/month [15]. So, US households access 10 Mb per person at about $1.00 per Mb, while SARI staff operate with .109 Mbps, or about 1% the amount of bandwidth per person, at a cost that is 228 times more expensive.

Importance of measurement

Using a standard SpeedTest utility the SARI network on two sample days (October 18 and 22, 2018) took several minutes to send a one word "test" message. The utility timed out on the 18th and achieved only minimal functionality on the 22nd (Figure 5).

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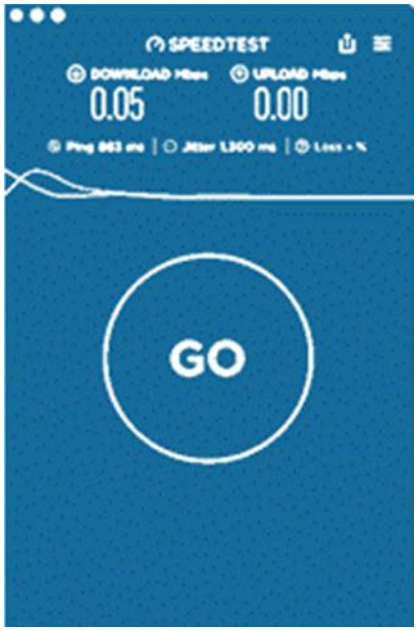

Figure 5. October 22, 2018 SpeedTest Utility Results

These levels fall below the minimally acceptable level of 128 Kbps for non-high-speed users (with a rating of 50 Kbps). Additionally, the connection at SARI on those days suffered from unusually high Ping and Jitter numbers. These results reinforce previous reports from SIL and SARI staff members that the 2Mbps network was essentially useless, particularly during regular office hours, and users would find access to the internet through other means. As soon as a few users had logged onto the network, the bandwidth would immediately become over-saturated and performance would degrade rapidly.

The following day, October 23, 2018, the engineers from MTN arrived at SARI's headquarters in Nyankpala to conduct the cutover of services from Vodaphone Ghana's 2Mbps connection to the new 10Mbps MTN connection. The research team conducted new tests soon after the changeover and showed that the network conditions improved (Figure 6). Word though had not yet spread throughout SARI that network bandwidth to the internet had just expanded five-fold, so traffic was minimal.

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Figure 6. October 23, 2018 SpeedTest Utility Results

ICT Health Checkup Results: The Savanna Agricultural Research Institute

Connectivity Cell D-14 – the level of SARI's connectivity

As previously indicated, one of the most critical starting points in ICT system analysis involves establishing the number and type of network users, and the associated network services each requires. There are currently 140 users on SARI's network at Nyankpala, 40 of whom required high-bandwidth accounts. Those data populate the appropriate fields in the initial Connectivity worksheet inside the ITC Health Checkup. SARI contracted for a bandwidth level of 10 Mbps and intended to operate all video-conferencing activities out of a single conference room. The results in cell "**Connectivity D-14**" show that SARI's newly agreed upon 10Mb shared connection was 27.28 Mbps short of meeting SARI's recommended minimum bandwidth requirements for an institutional configuration with only one site for video- conferencing/high-bandwidth traffic (Figure 7). Even though SARI had just upgraded their connectivity for the main Nyankpala station by a full 5X beyond their initial 2Mbps bandwidth, with their new 10

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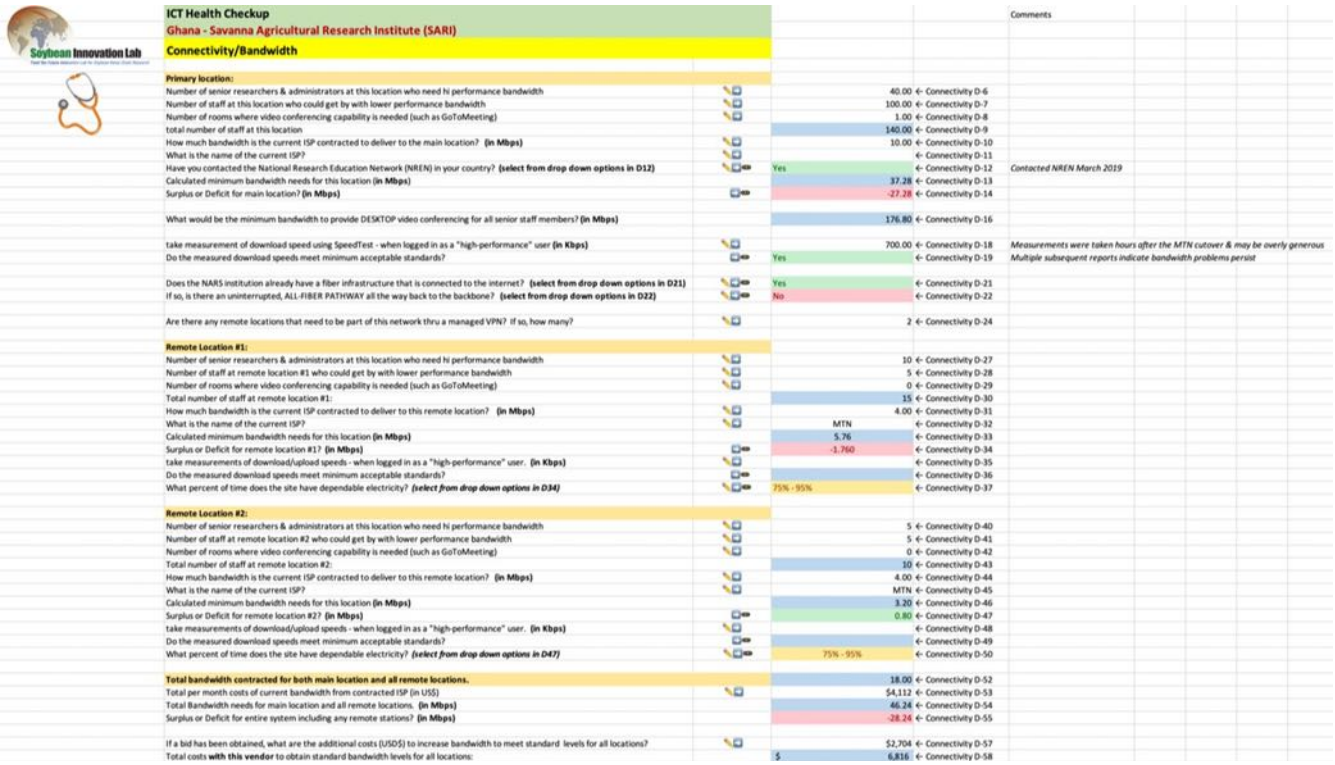
Mbps connection at Nyankpala, they were still only providing about 27% of what the ICT Health Checkup recommends as a minimum allocation for SARI's size and needs.

Furthermore, it should be stressed that the calculated result in cell "**Connectivity D-13**" shows a **minimum** recommended bandwidth level of 37.28 Mbps for the main Nyankpala station. However, that minimum requires all 40 senior scientists and researchers to share a single video-conferencing facility, as opposed to being able to spontaneously start up a video-conference from their own desktop with no prior scheduling, approval, or coordination with colleagues.

Connectivity Cell D-16 – the recommended level for SARI's connectivity

The embedded formula in cell "**Connectivity D-16**" of the ICT Health Checkup reveals that

SARI requires a shared bandwidth for their main station of 177 Mbps in order for all senior scientists



ICT Health Checkup				Comments
Ghana - Savanna Agricultural Research Institute (SARI)				
Connectivity/Bandwidth				
Primary location:				
Number of senior researchers & administrators at this location who need hi performance bandwidth			40.00 ← Connectivity D-6	
Number of staff at this location who could get by with lower performance bandwidth			100.00 ← Connectivity D-7	
Number of rooms where video conferencing capability is needed (such as GoToMeeting)			1.00 ← Connectivity D-8	
total number of staff at this location			140.00 ← Connectivity D-9	
How much bandwidth is the current ISP contracted to deliver to the main location? **(in Mbps)**			10.00 ← Connectivity D-10	
What is the name of the current ISP?			← Connectivity D-11	
Have you contacted the National Research Education Network (NREN) in your country? **(select from drop down options in D12)**		Yes	← Connectivity D-12	*Contacted NREN March 2019*
Calculated minimum bandwidth needs for this location **(in Mbps)**			37.28 ← Connectivity D-13	
Surplus or Deficit for main location? **(in Mbps)**			-27.28 ← Connectivity D-14	
What would be the minimum bandwidth to provide DESKTOP video conferencing for all senior staff members? **(in Mbps)**			176.80 ← Connectivity D-16	
take measurement of download speed using SpeedTest - when logged in as a "high-performance" user **(in Kbps)**			700.00 ← Connectivity D-18	*Measurements were taken hours after the MTN cutover & may be overly generous*
Do the measured download speeds meet minimum acceptable standards?		Yes	← Connectivity D-19	*Multiple subsequent reports indicate bandwidth problems persist*
Does the NARS institution already have a fiber infrastructure that is connected to the internet? **(select from drop down options in D21)**		Yes	← Connectivity D-21	
If so, is there an uninterrupted, ALL-FIBER PATHWAY all the way back to the backbone? **(select from drop down options in D22)**		No	← Connectivity D-22	
Are there any remote locations that need to be part of this network thru a managed VPN? If so, how many?			2 ← Connectivity D-24	
Remote Location #1:				
Number of senior researchers & administrators at this location who need hi performance bandwidth			10 ← Connectivity D-27	
Number of staff at remote location #1 who could get by with lower performance bandwidth			5 ← Connectivity D-28	
Number of rooms where video conferencing capability is needed (such as GoToMeeting)			0 ← Connectivity D-29	
Total number of staff at remote location #1:			15 ← Connectivity D-30	
How much bandwidth is the current ISP contracted to deliver to this remote location? **(in Mbps)**			4.00 ← Connectivity D-31	
What is the name of the current ISP?		MTN	← Connectivity D-32	
Calculated minimum bandwidth needs for this location **(in Mbps)**		5.76	← Connectivity D-33	
Surplus or Deficit for remote location #1? **(in Mbps)**		-1.760	← Connectivity D-34	
take measurements of download/upload speeds - when logged in as a "high-performance" user. **(in Kbps)**			← Connectivity D-35	
Do the measured download speeds meet minimum acceptable standards?			← Connectivity D-36	
What percent of time does the site have dependable electricity? ***(select from drop down options in D34)***		75% - 95%	← Connectivity D-37	
Remote Location #2:				
Number of senior researchers & administrators at this location who need hi performance bandwidth			5 ← Connectivity D-40	
Number of staff at remote location #2 who could get by with lower performance bandwidth			5 ← Connectivity D-41	
Number of rooms where video conferencing capability is needed (such as GoToMeeting)			0 ← Connectivity D-42	
Total number of staff at remote location #2:			10 ← Connectivity D-43	
How much bandwidth is the current ISP contracted to deliver to this remote location? **(in Mbps)**			4.00 ← Connectivity D-44	
What is the name of the current ISP?			MTN ← Connectivity D-45	
Calculated minimum bandwidth needs for this location **(in Mbps)**			3.20 ← Connectivity D-46	
Surplus or Deficit for remote location #2? **(in Mbps)**			0.80 ← Connectivity D-47	
take measurements of download/upload speeds - when logged in as a "high-performance" user. **(in Kbps)**			← Connectivity D-48	
Do the measured download speeds meet minimum acceptable standards?			← Connectivity D-49	
What percent of time does the site have dependable electricity? ***(select from drop down options in D47)***		75% - 95%	← Connectivity D-50	
Total bandwidth contracted for both main location and all remote locations.			18.00 ← Connectivity D-52	
Total per month costs of current bandwidth from contracted ISP (in US$)			$4,112 ← Connectivity D-53	
Total Bandwidth needs for main location and all remote locations. **(in Mbps)**			46.24 ← Connectivity D-54	
Surplus or Deficit for entire system including any remote stations? **(in Mbps)**			-28.24 ← Connectivity D-55	
If a bid has been obtained, what are the additional costs (USD$) to increase bandwidth to meet standard levels for all locations?			$2,704 ← Connectivity D-57	
Total costs **with this vendor** to obtain standard bandwidth levels for all locations:		$	6,816 ← Connectivity D-58	

Figure 7: The State of Connectivity/Bandwidth

and administrators to have a guaranteed 4Mbps connection from their desktop. Nonetheless, it is understandable why SARI chose not to purchase 177 Mbps worth of bandwidth from MTN given MTN's current pricing structure. On the other hand, video conferencing and web-based outreach have become essential. Only offering a central location severely limits researchers' ability to collaborate with others.

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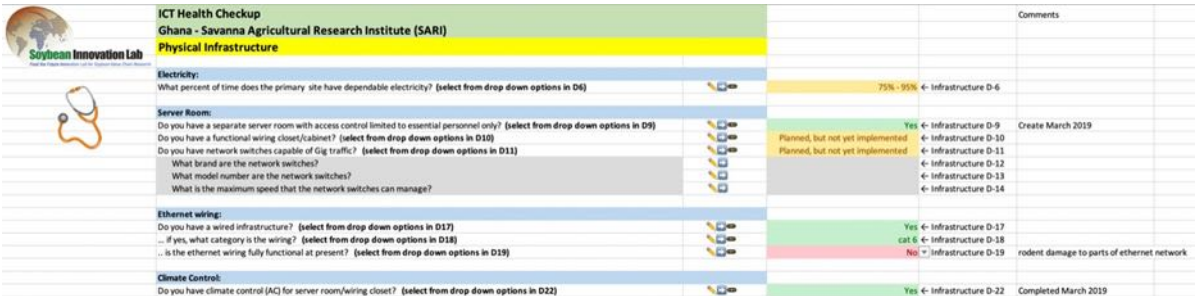
In sum, all of these bandwidth decisions have significant programmatic and productivity consequences for the scientists and their teams at SARI. The increase to 177Mbps from what was originally available at 2Mbps at Nyankpala, amounts to a 9000% increase in bandwidth. Increasing from their current 18Mbps service for all three stations, Nyankpala, Wa, Manga to 177Mbps for Nyankpala alone would raise the annual cost as much as tenfold from $49,000 to $485,000 at current pricing with their current commercial vendor. The gap in bandwidth and costs between SARI's current state and where they need to underscore the importance of discovering an alternative that raises access and lowers connectivity costs.

Physical Infrastructure

The next major tab on the ICT Health Checkup provides an assessment of the state and existence of all the necessary physical infrastructural elements needed for ICT connectivity to work properly. Most of the necessary physical infrastructural elements are still in process of implementation at SARI, thus show "yellow" or "red" shaded cells (Figure 8). For example, recent improvements include the creation of a separate server room and the addition of air conditioning for that room. Meantime still pending are improving the dependability of the electricity source, creating a functional wiring closet, and installing gig capable network switches. The red shading in "Infrastructure D-19" reflects recent damage to ethernet cabling from a rodent infestation. Local ICT managers have put together a plan to address the problem, and implementation is forthcoming.



ICT Health Checkup				Comments
Ghana - Savanna Agricultural Research Institute (SARI)				
Physical Infrastructure				
Electricity:				
What percent of time does the primary site have dependable electricity? **(select from drop down options in D6)**		75% - 95%	← Infrastructure D-6	
Server Room:				
Do you have a separate server room with access control limited to essential personnel only? **(select from drop down options in D9)**		Yes	← Infrastructure D-9	Create March 2019
Do you have a functional wiring closet/cabinet? **(select from drop down options in D10)**		Planned, but not yet implemented	← Infrastructure D-10	
Do you have network switches capable of Gig traffic? **(select from drop down options in D11)**		Planned, but not yet implemented	← Infrastructure D-11	
What brand are the network switches?			← Infrastructure D-12	
What model number are the network switches?			← Infrastructure D-13	
What is the maximum speed that the network switches can manage?			← Infrastructure D-14	
Ethernet wiring:				
Do you have a wired infrastructure? **(select from drop down options in D17)**		Yes	← Infrastructure D-17	
... if yes, what category is the wiring? **(select from drop down options in D18)**		cat 6	← Infrastructure D-18	
... is the ethernet wiring fully functional at present? **(select from drop down options in D19)**		No	← Infrastructure D-19	rodent damage to parts of ethernet network
Climate Control:				
Do you have climate control (AC) for server room/wiring closet? **(select from drop down options in D22)**		Yes	← Infrastructure D-22	Completed March 2019

Figure 8. The State of Physical Infrastructure

Intranet Services

The next major tab in the ICT Health Checkup addresses the quality of intranet services available to the researchers, administrators, and other staff members at SARI (Figure 9). That part of the Checkup provides a long list of desirable services, and it is notable that only one of them has a green shading. Most (18) of the cells display a yellow shading indicating that improvements are in the planning stage, with implementation still pending. Many of the desired intranet service issues will remain unaddressed until the arrival of sufficient bandwidth. Four cells that currently show a red shaded alarm require implementation, but only after all the "yellow" items have been successfully "turned green".

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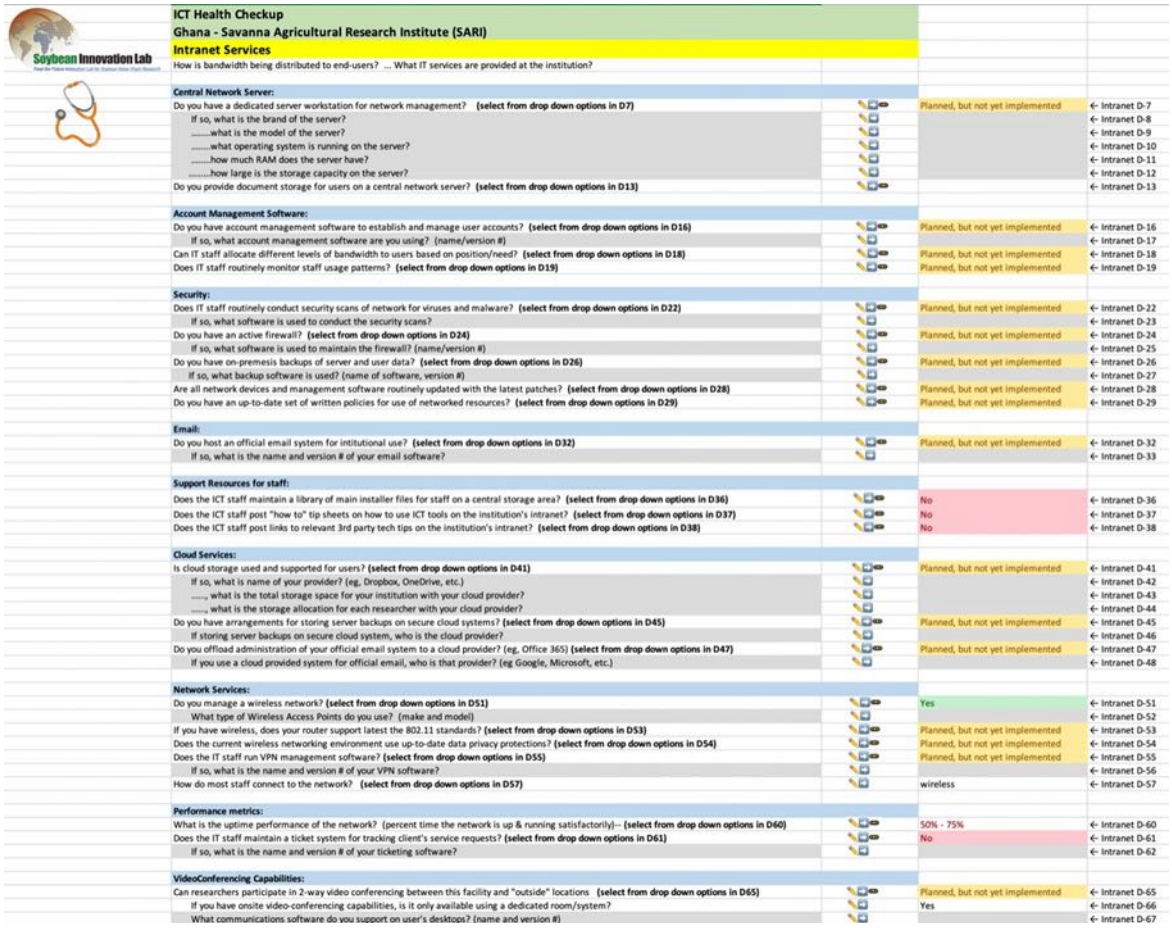

ICT Health Checkup Ghana - Savanna Agricultural Research Institute (SARI) Intranet Services How is bandwidth being distributed to end-users? ... What IT services are provided at the institution?			
Central Network Server:			
Do you have a dedicated server workstation for network management? **(select from drop down options in D7)**		Planned, but not yet implemented	← Intranet D-7
If so, what is the brand of the server?			← Intranet D-8
.....what is the model of the server?			← Intranet D-9
.....what operating system is running on the server?			← Intranet D-10
.....how much RAM does the server have?			← Intranet D-11
.....how large is the storage capacity on the server?			← Intranet D-12
Do you provide document storage for users on a central network server? **(select from drop down options in D13)**			← Intranet D-13
Account Management Software:			
Do you have account management software to establish and manage user accounts? **(select from drop down options in D16)**		Planned, but not yet implemented	← Intranet D-16
If so, what account management software are you using? (name/version #)			← Intranet D-17
Can IT staff allocate different levels of bandwidth to users based on position/need? **(select from drop down options in D18)**		Planned, but not yet implemented	← Intranet D-18
Does IT staff routinely monitor staff usage patterns? **(select from drop down options in D19)**		Planned, but not yet implemented	← Intranet D-19
Security:			
Does IT staff routinely conduct security scans of network for viruses and malware? **(select from drop down options in D22)**		Planned, but not yet implemented	← Intranet D-22
If so, what software is used to conduct the security scans?			← Intranet D-23
Do you have an active firewall? **(select from drop down options in D24)**		Planned, but not yet implemented	← Intranet D-24
If so, what software is used to maintain the firewall? (name/version #)			← Intranet D-25
Do you have on-premesis backups of server and user data? **(select from drop down options in D26)**		Planned, but not yet implemented	← Intranet D-26
If so, what backup software is used? (name of software, version #)			← Intranet D-27
Are all network devices and management software routinely updated with the latest patches? **(select from drop down options in D28)**		Planned, but not yet implemented	← Intranet D-28
Do you have an up-to-date set of written policies for use of networked resources? **(select from drop down options in D29)**		Planned, but not yet implemented	← Intranet D-29
Email:			
Do you host an official email system for intitutional use? **(select from drop down options in D32)**		Planned, but not yet implemented	← Intranet D-32
If so, what is the name and version # of your email software?			← Intranet D-33
Support Resources for staff:			
Does the ICT staff maintain a library of main installer files for staff on a central storage area? **(select from drop down options in D36)**		No	← Intranet D-36
Does the ICT staff post "how to" tip sheets on how to use ICT tools on the institution's intranet? **(select from drop down options in D37)**		No	← Intranet D-37
Does the ICT staff post links to relevant 3rd party tech tips on the institution's intranet? **(select from drop down options in D38)**		No	← Intranet D-38
Cloud Services:			
Is cloud storage used and supported for users? **(select from drop down options in D41)**		Planned, but not yet implemented	← Intranet D-41
If so, what is name of your provider? (eg, Dropbox, OneDrive, etc.)			← Intranet D-42
....., what is the total storage space for your institution with your cloud provider?			← Intranet D-43
....., what is the storage allocation for each researcher with your cloud provider?			← Intranet D-44
Do you have arrangements for storing server backups on secure cloud systems? **(select from drop down options in D45)**		Planned, but not yet implemented	← Intranet D-45
If storing server backups on secure cloud system, who is the cloud provider?			← Intranet D-46
Do you offload administration of your official email system to a cloud provider? (eg, Office 365) **(select from drop down options in D47)**		Planned, but not yet implemented	← Intranet D-47
If you use a cloud provided system for official email, who is that provider? (eg Google, Microsoft, etc.)			← Intranet D-48
Network Services:			
Do you manage a wireless network? **(select from drop down options in D51)**		Yes	← Intranet D-51
What type of Wireless Access Points do you use? (make and model)			← Intranet D-52
If you have wireless, does your router support latest the 802.11 standards? **(select from drop down options in D53)**		Planned, but not yet implemented	← Intranet D-53
Does the current wireless networking environment use up-to-date data privacy protections? **(select from drop down options in D54)**		Planned, but not yet implemented	← Intranet D-54
Does the IT staff run VPN management software? **(select from drop down options in D55)**		Planned, but not yet implemented	← Intranet D-55
If so, what is the name and version # of your VPN software?			← Intranet D-56
How do most staff connect to the network? **(select from drop down options in D57)**		wireless	← Intranet D-57
Performance metrics:			
What is the uptime performance of the network? (percent time the network is up & running satisfactorily)-- **(select from drop down options in D60)**		50% - 75%	← Intranet D-60
Does the IT staff maintain a ticket system for tracking client's service requests? **(select from drop down options in D61)**		No	← Intranet D-61
If so, what is the name and version # of your ticketing software?			← Intranet D-62
VideoConferencing Capabilities:			
Can researchers participate in 2-way video conferencing between this facility and "outside" locations **(select from drop down options in D65)**		Planned, but not yet implemented	← Intranet D-65
If you have onsite video-conferencing capabilities, is it only available using a dedicated room/system?		Yes	← Intranet D-66
What communications software do you support on user's desktops? (name and version #)			← Intranet D-67

Figure 9. The State of Intranet Services

IT Professional Staff

The final tab in the ICT Heath Checkup deals with the IT Professional Staff members, and as such, would not be appropriate to share some of the personnel related data in this case study because of issues of personal privacy and confidentiality (Figure 10). With respect to other important ICT staff issues, the Checkup reveals that formal ICT technical training is inadequate at SARI due to limited financial resources. Also, the administration does not fully integrate ICT staff into senior ICT planning, nor do they have ICT budgetary control and responsibility. All three are an essential feature of the "mission critical" theme of research connectivity and operational success.

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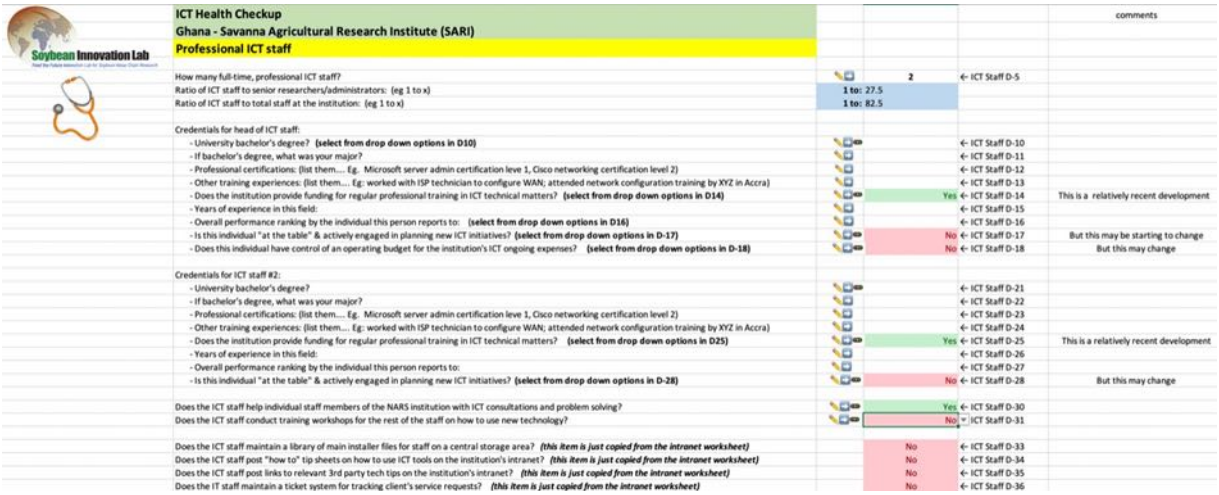

ICT Health Checkup Ghana - Savanna Agricultural Research Institute (SARI) Professional ICT staff				comments
How many full-time, professional ICT staff?		2	← ICT Staff D-5	
Ratio of ICT staff to senior researchers/administrators: (eg 1 to x)		1 to: 27.5		
Ratio of ICT staff to total staff at the institution: (eg 1 to x)		1 to: 82.5		
Credentials for head of ICT staff:				
- University bachelor's degree? **(select from drop down options in D10)**			← ICT Staff D-10	
- If bachelor's degree, what was your major?			← ICT Staff D-11	
- Professional certifications: (list them.... Eg. Microsoft server admin certification leve 1, Cisco networking certification level 2)			← ICT Staff D-12	
- Other training experiences: (list them.... Eg: worked with ISP technician to configure WAN; attended network configuration training by XYZ in Accra)			← ICT Staff D-13	
- Does the institution provide funding for regular professional training in ICT technical matters? **(select from drop down options in D14)**		Yes	← ICT Staff D-14	This is a relatively recent development
- Years of experience in this field:			← ICT Staff D-15	
- Overall performance ranking by the individual this person reports to: **(select from drop down options in D16)**			← ICT Staff D-16	
- Is this individual "at the table" & actively engaged in planning new ICT initiatives? **(select from drop down options in D-17)**		No	← ICT Staff D-17	But this may be starting to change
- Does this individual have control of an operating budget for the institution's ICT ongoing expenses? **(select from drop down options in D-18)**		No	← ICT Staff D-18	But this may change
Credentials for ICT staff #2:				
- University bachelor's degree?			← ICT Staff D-21	
- If bachelor's degree, what was your major?			← ICT Staff D-22	
- Professional certifications: (list them.... Eg. Microsoft server admin certification leve 1, Cisco networking certification level 2)			← ICT Staff D-23	
- Other training experiences: (list them.... Eg: worked with ISP technician to configure WAN; attended network configuration training by XYZ in Accra)			← ICT Staff D-24	
- Does the institution provide funding for regular professional training in ICT technical matters? **(select from drop down options in D25)**		Yes	← ICT Staff D-25	This is a relatively recent development
- Years of experience in this field:			← ICT Staff D-26	
- Overall performance ranking by the individual this person reports to:			← ICT Staff D-27	
- Is this individual "at the table" & actively engaged in planning new ICT initiatives? **(select from drop down options in D-28)**		No	← ICT Staff D-28	But this may change
Does the ICT staff help individual staff members of the NARS institution with ICT consultations and problem solving?		Yes	← ICT Staff D-30	
Does the ICT staff conduct training workshops for the rest of the staff on how to use new technology?		No	← ICT Staff D-31	
Does the ICT staff maintain a library of main installer files for staff on a central storage area? ***(this item is just copied from the intranet worksheet)***		No	← ICT Staff D-33	
Does the ICT staff post "how to" tip sheets on how to use ICT tools on the institution's intranet? ***(this item is just copied from the intranet worksheet)***		No	← ICT Staff D-34	
Does the ICT staff post links to relevant 3rd party tech tips on the institution's intranet? ***(this item is just copied from the intranet worksheet)***		No	← ICT Staff D-35	
Does the IT staff maintain a ticket system for tracking client's service requests? ***(this item is just copied from the intranet worksheet)***		No	← ICT Staff D-36	

Figure 10. The State of Professional ICT Staff

CONCLUSION

It is important to note the case of SARI, which reflects two fundamental themes associated with the NARS connectivity issue. The first theme is the choice between a telecom solution and the NREN option. Telecoms are established market leaders and already serve NARS administration and staff as consumer customers. Thus, SARI personnel are fairly familiar with the telecoms and their services, and they might appear to be a logical solution for SARI [16], but are insufficient to meet the modern needs of a researcher.

The second theme is the novelty of the ICT strategy of aggregation and the economies of scale. Having NARS and higher education institutions work together presents a new practice that deviates from traditional procurement practices of utilities, such as electricity. Thus, the concept of collaboration within the ICT space is novel and not well understood [16,17]. For example, at the time of this study, SARI was unaware of the Ghana Academic Research Network (GARNET) as a potential aggregation solution. As well, GARNET was unaware of SARI's connectivity challenges [18]. Addressing this information gap from both perspectives (NARS and NREN) becomes critical going forward.

In this case study at SARI, the challenges of how to overcome poor ICT connectivity and provide smoothly functioning ICT services throughout the institution present itself as a complex system of inter-related and highly technical issues. The inherent technical nature of the subject, ICT being a discipline apart from agricultural sciences, and the complexity of institutional connectivity, may challenge NARS institutional administrators and IT staff. The new ICT Health Checkup helps address these challenges by enabling NARS leaders to break the process down into a set of manageable, measurable steps. The Checkup also helps administrators establish greater specificity and formal system metrics, which are essential for discussions with service providers, such as the local NREN. The process of utilizing standard criteria for measuring the connectivity needs for both researchers and support staff provides a structured way to understand the multiple variables involved, and determine both what would be minimally acceptable as well as what would be more ideally desirable.

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At SARI, the high cost of connectivity via commercial cellular providers severely limits the productivity and programmatic output of SARI. Therefore, NARS institutions should look first to their local NREN for accessing high-speed and affordable bandwidth, and only turn to commercial cellular providers as their last option. The National Research and Education Network sees addressing the unique high capacity bandwidth needs of research institutions and universities as its sole purpose. As such, the NRENs favorably position themselves to help bandwidth-challenged NARS institutions.

Beyond the issue of obtaining sufficient bandwidth, is the challenge of developing a professional IT staff to develop and implement a comprehensive plan to upgrade SARI's ICT system. This requires highly trained IT staff members and a commitment on the part of the institution, and the research system in general, to support staff with adequate training, budgetary resources, and management authority. Charging, and then allocating, sufficient overhead as part of research grant budgets serves as a common practice among research and academic institutions for users to fund the network.

Not explicitly addressed in this manuscript is the interaction between R&D support for the NARS and the success of the linked development activities to reduce poverty and malnutrition in the region. Significant resources for rural economic development often include direct and active collaboration with the NARS as the key technical resource partner. However, without the "oxygen" of connectivity, the NARS partner struggles to keep pace with the needs of the development project and the key stakeholders. The lack of connectivity stifles collaboration and innovation, and co-creation of development solutions cannot take place. Empowerment of local NARS actors to lead development, rather than follow, cannot take place because low bandwidth is so isolating. Unfortunately, innovation and relevant development technologies, such as farmer IT applications, often originate overseas, and the jobs and economic multiplier opportunities for the national economics do not occur. Greater connectivity would allow the NARS to become technology hubs and drive innovation in the country by leveraging their understanding of local needs. So additional research needs to take place that will measure the returns to development impact as a function of the level of connectivity. Development dollars would not only be significantly better spent when local NARS partners have robust access to the internet, but also the effects of development would be much more sustainable and local capacity would emerge much more quickly.

Finally, we should generalize the results of this case study with caution as the data only reflect one institution. The research team, though, sees the connectivity challenges consistently repeat themselves across the many institutions from over 20 countries in the developing world. However, policy makers and donors need more data and the subsequent analyses from more institutions in order to confirm the dominant ICT themes and challenges. To this end, the research team and its partners have now gathered information from a total of 18 institutions and organizations; with complete ICT Health Checkup Data on 9 NARS institutions in 3 countries that span west and south-central Africa. Additional data gathering activities are planned for the near future in additional locations. Forthcoming, will be research that provides a more robust picture of the state of NARS ICT connectivity.

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Table 1: Study Respondents

	All	Technical	Researcher	Technical		Researcher	
				of All	of Tech.	of All	of Res.
UI	12	10	2	22%	53%	4%	7%
UDS	4	1	3	2%	5%	7%	11%
UG	2	2	0	4%	11%	0%	0%
				28%	68%		
Ghana	2	2	0	4%	11%	0%	0%
Mozambique	1	1	0	2%	5%	0%	0%
Zimbabwe	1	1	0	2%	5%	0%	0%
SARI	9	2	7	4%	11%	15%	26%
SIL	10	0	10	0%	0%	22%	37%
International	5	0	5	0%	0%	11%	19%
	46	19	27				
		41%	59%				

Note: UI = University of Illinois (United States); UDS = University for Development Studies (Ghana); UG = University of Ghana (Ghana)

REFERENCES

1. **The Chronicle of Higher Education.** The Hard Choices of Academic Technology. Retrieved July, 2019 from http://images.results.chronicle.com/Web/TheChronicleofHigherEducation/%7B02b593e6-6402-46fb-8bb5a3320ddad521%7D_TechDecisions_ResearchBrief_Workday_v4.pdf , 2019.

2. **Chaparro F and NARS Secretariat** Towards a Global Agricultural Research System: A NARS Perspective. **In**: European Forum on Agricultural Research for Development, Wageningen, the Netherlands, April, pp. 7-8. 1999.

3. **Maru A** "ICT/ICM in agricultural research and development: status in sub-Saharan Africa." In a *background paper for Forum for Agricultural Research in Africa (FARA)/Regional Agricultural Information System (RAIS) Workshop, Accra, Ghana*. 2004.

4. **Yonazi E, Tim K, Naomi H and C Blackman** The transformational use of information and communication technologies in Africa. World Bank, 2012.

5. **Foley M** The Role and Status of National Research and Education Networks in Africa. World Bank, 2016.

6. **Muriithi P, David H and L Pemberton** Factors contributing to adoption and use of information and communication technologies within research collaborations in Kenya. *Information Technology for Development* 22, no. sup1 (2016): 84-100.

7. **Ince K, Aitken J, and W George** U.S. Patent No. 9,282,174. Washington, DC: U.S. Patent and Trademark Office, 2014.

8. **Patil P, Akram H, Yogesh B and A Gokhale** Enabling software-defined networking for wireless mesh networks in smart environments. In *2016 IEEE 15th International Symposium on Network Computing and Applications (NCA)*, pp. 153-157. IEEE, 2016.

9. **Lunden JP, Virtej E, Malkamäki EM, Moisio MJ and AS Sorri** *U.S. Patent No.9,906,974*. Washington, DC: U.S. Patent and Trademark Office, 2018.

10. **Tibben WJ** Theory building for ICT4D: Systemizing case study research using theory triangulation. *Information Technology for Development* 21, no. 4 (2015): 628-652.

11. **Sein MK, Devinder T, Mathias H and Ø Sæbø** A holistic perspective on the theoretical foundations for ICT4D research. *Information Technology for Development* 25, no. 1 (2019): 7-25.

12. **Ragin CC and HS Becker** What is a case?: Exploring the foundations of social inquiry. Cambridge university press, 1992.

13. **Pfigu K** Report on IT Network Designing and Engineering for SARI in Northern Ghana Region. USAID- ATT project, 2017, 18 pages.

14a. **Senior Administrator.** Personal communication. SARI. March, 2019.

14b. **Senior Administrator.** Personal communication. SARI. March, 2019**.**

15. **Tom's G, and D Reisinger** How Much Internet Speed Should You Really Pay For? Retrieved April 24, 2019, from https://www.tomsguide.com/us/internet-speed-what-you-need,news-24289.html, 2019.

16. **Senior Administrator.** Personal communication. SARI. March, 2019.

17. **Senior ICT Administrator.** Personal communication. SARI. October, 2018.

18. **Senior Administrator.** Personal communication. GARNET, July, 2019.