A Data-Driven Approach to Sustainable Agriculture

Khaled Md Saifullah and Tanvir Quader Chowdhury

a2i (Aspire to Innovate), Dhaka, Bangladesh

Abstract

The adverse effects of multiple challenges cause farmers to face unsustainable livelihoods. The solution to this challenge is to make a data-driven ecosystem for farmers and other stakeholders in the agriculture sector. Farmers need granular data on rainfall patterns, water cycles, fertilizer requirements, and more to ensure a sustainable agricultural system. Big Data Farming has proven to be an effective technique for gathering and analysing agricultural data from private and public stakeholders, social media, sensors, GPS, and private and other internet sources. The use of technology such as the Internet of Things (IoT), Big Data Farming, cloud computing, and analytics will enable farmers to enhance the entire process in real-time significantly. Therefore, a Smart Agriculture data-driven ecosystem is required to enable smart devices or solutions to optimize agricultural resources. The ecosystem will also ensure climate-sensitive forecasting for the farmers to make production and harvesting more efficient. This research mainly aims to assess the global practices of data-driven approach and outline a proposed framework of such approach in respect to Bangladesh's context. Case study from India, Estonia and Singapore proved to be successful upon development of the digital stack. Hence, looking in the context of Bangladesh, the layers were defined accordingly. Findings from this study stated that Bangladesh should build 5 layers (Identity, Payment, Data, Service, and Access) to ensure sustainability and encompass everything under one platform. Also, necessary provision should be updated or formulated in order to empower the layers functionality.

Keywords: Big Data, Digital Agriculture, Data Analytics, Dashboard, Data Warehouse, Forecasting

Background

Global footprints of data-driven approach have always shown evident results in sectoral implementation. Over the decades, implementors around the world have attained significant results with the facilitation of such approach including improvement in crop yields, cost reduction, and enhancement in sustainability (Henke et al., 2016). Real-time use cases of similar approach are in use all over the world.

Similarly, fable of such approach has woven the data-driven ecosystem in Africa. The Covid-19 and food system in Africa region illustrate the attainment of food supply-chain resiliency through the inclusion of data revolution. The impact of Covid-19 widened the gap in African food system and threatened the entire supply-chain. During covid-19, experts anticipated that the impact could decline the food import supply-chain from 13% to 25% and push 20 million people to hunger. It was implied that the impact of Covid-19 couldn't be withstood because the data capacity was not sufficient to enable strategic and targeted interventions to protect African food system. Major reason behind such cause appeared to be high digital divide among the African population. According to sources, mobile penetration rates in Africa is around 45% with only 40.3% of youth exposed to internet and 74 million women unconnected in any digital means ("Data-Driven Food Systems for Crisis Resiliency," 2020).

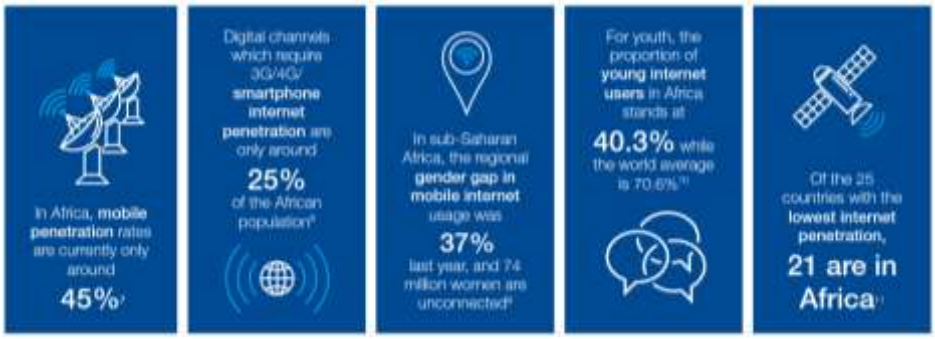

Figure: Africa Digital Inclusion Statistics
Source: "Data-Driven Food Systems for Crisis Resiliency," 2020

However, the Covid-19 predicament has also brought necessary digital revolution to take informed and targeted decision to shift the food system in a positive manner. Leveraging this opportunity, business, government, civil society, and innovators begins to leverage data-driven approach to enhance resiliency. Analytics-driven insights have showed positive results in driving organizations, governments and businesses to achieve exponential growth and sustainability ("Data-Driven Food Systems for Crisis Resiliency," 2020).

The inception of Digital Bangladesh has reduced existing challenges including poverty, food insecurity, food supply-chain, etc. Given the nation's stellar performance with the Millennium Development Goals (MDGs), the nation is now being looked upon as a potential country with respect to achieving the Sustainable Development Goals (SDGs). According to the BBS census in 2008, Bangladesh was home to around 14 million smallholder farmer families, a number that has doubled since then ("Smallholders Need Intensive Care," 2022). These families are operating in a farm size of 5 to 249 decimals. Over the years, the agriculture sector has acted as one of the core pillars behind Bangladesh's success in decreasing poverty, ensuring food security for 169.4 million population, and enabling employment opportunities for 41 percent of the labour force. About 50 percent of people depend on agriculture for their livelihood (Imdad, 2021). The figure below shows the exponential growth in rice production over the span of 45 years.

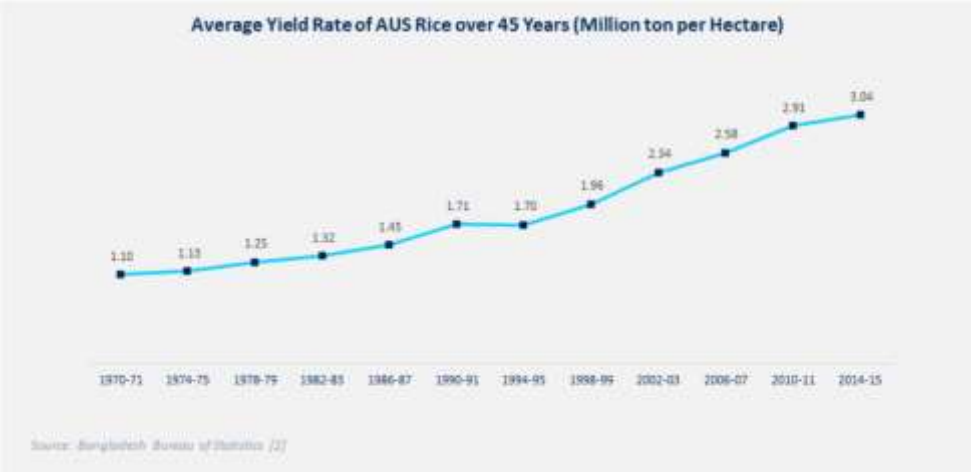

Figure: Average Yield of AUS Rice over 45 years (Million tons per hectare)
Source: 45 years Agriculture Statistics of Major Crops (Aus, Amon, Boro, Jute, Potato& Wheat), 2018

Despite the nation's stellar performance, agricultural centric challenges still exist and create disturbance within the ecosystem. For instance, in the year of 2008, around 100,000 ha productive agricultural land was degrading per year due to non-agricultural usage. River banks erosion impact was around one million people within a range of 150 upazilas (Shaikh, 2008). Challenges as such accelerated major issues like food insecurity till now in a developing country like Bangladesh where 160 million of the population are needed to be fed continuously. Therefore, it is pertinent for Bangladesh to enable the full potential of the agriculture sector through the establishment of a data-driven ecosystem. The ecosystem will enable digital services which will provide farmers access to information, market, and finance.

Specific Problems to Address

The journey till Smart Bangladesh has capacitated the Bangladesh government to build digital services with common principles, minimizing time, cost, and the number of visits for farmers to access services. This process of digitization led Bangladesh to focus only on the traditional, organizational structure of government rather than the needs of the farmers. Government ministries and departments have only undertaken fragmented approaches to establish their online presence but resulting in zero scaleup of digital services.

The current condition of any smallholder farmer while availing a digital service require the provision of same information to different organization. Not only does cause repetition of information but this often means that it is impossible for government or any business body to build integrated services because the data are insufficient and not interoperable between the primary stakeholders. As a result, it becomes tough for a service provider to identify the right farmer and deliver targeted service. Inadequate data accessibility, duplicity among data, and failure to cover 100% of the farmers and relevant stakeholders is a key obstacle against the enablement of digital services that is failing to scaleup across the nation (World Bank, 2018).

Case study of smallholder farmers in Barind Tract, a lowland area in the northwest region of Bangladesh where water scarcity is a significant challenge for an efficient production system. Due to the extremely dry nature of the climate, there is very little rainfall within that area which fails to replenish the groundwater system correctly. As a result, it becomes an arid region and makes the production cost of agricultural products more cost-inefficient within that area. For instance, the electricity charge for irrigation is up to 100 to 150 percent (Sajid, 2020). Overall, the adverse effects of multiple challenges cause smallholder farmers to face unsustainable livelihoods. The smallholder farmers in the Barind Tract region face multiple challenges, including low production, farm efficiency, and limited access to farmer-friendly smart solutions. These challenges make it difficult for them to withstand unforeseeable events, which lead to financial hardship and high-interest debt.

Overall, the specific challenges the smallholder farmer in Barind Tract region faces:

- **Access to information, finance, market, and resources:** Due to the absence of integrated service delivery platforms for farmers, inefficient access to information, finance, market and resources like seeds, fertilizers, equipment, etc hinders farmers to achieve maximum yield.
- **Multi-layered real-time decision-making:** Agriculture sector policymakers, research organisations, and government authorities face problems in decision-making because of challenges associated with data accumulation, sorting, and analysing. Also, farmers are unable to take agri-production decisions and climate-sensitive decisions due to a lack of insight from agri data and data literacy.

All these existing challenges prevails within the region of Barind Tract or similar areas because the government or private sector stakeholders lack the access to the holistic data of all farmers across the nation.

Research Methodology

Research Objective

Sustainable and digitized agriculture interventions can play a key role in increasing productivity, accessibility, and quality of agricultural products along with uplifting farmers living standards. With the aim of fostering technological innovation in the agriculture sector and develop smart farmers to address the future impact of 4IR. This research aims to assess the global practices of data-driven approach and outline a proposed framework of such approach in respect to Bangladesh's context.

Research Questions

The following research questions that will be addressed throughout this study:

- What are the data-driven approaches adopted to achieve sustainable and smart agriculture?
- How have these approaches been implemented by countries to attain exponential growth and sustainability?
- What should be the layers required for Bangladesh to achieve data-driven agriculture?
-

Assessment of Peer-Reviewed Literatures

Assessment of literature reviews was conducted to address first question of the research. The literatures covered in the review section mostly emphasized on the digital data-driven approaches to sustainable and smart agriculture. The literatures used in this section were published in peer-reviewed journal and used variety electronic sources like Google Scholar.

Assessment of journeys adopted by India, Estonia and Singapore

The second question addressed in this research will be identified in the discussion section where the opportunities and challenges of India and Estonia will be assessed. In addition, based on the assessment recommendation will be provided in context of Bangladesh.

Proposed Concept

The third question addressed in this study identify the data-driven approach of India, Estonia, and Singapore. Critical assessment of these countries data-driven model, an outline was formulated. Moreover, the validation of proposed model was ensured through extensive analysis of available literatures covering statistical impact of data-driven model in India, Estonia, and Singapore. Their case studies were analysed thoroughly to develop the model and validate it properly.
The data was extracted primarily from sources operated by the government of India and Estonia. In addition, reports from world bank and other trustworthy sources were used to ensure authenticity.

Limitation

This study has one limitation which is the data-driven model assessed in this study does not reflect the implementation in agriculture sector. Moreover, accurate source of legal framework regarding the proposed data-driven model were not assessed properly because of proper limited sources. Despite the limitation, this review article provides a comprehensive analysis of the current use of mentioned models in other sectors. Reference from such model can be implemented in agriculture sector in a similar way. Few recommendations were provided based on the extensive analysis. Therefore, future assessment is required and it should address the limitations of this review by expanding the search strategy to include other countries using similar models.

Literature Review

As discussed, digital revolution has a role to play in order to enable sustainable agriculture. To comprehend the importance of data-driven approach in agriculture, it is compulsory to delve deep into the application of advanced technologies, IoT devices, and big data models. As a result, the existing literatures explore the role and application of emerging technologies in agriculture ecosystem and practices established around the world to achieve sustainable agriculture.

The role of IoT is constantly transforming the shape of agriculture by providing farmers with real-time information and support. Farooq et al. (2020) conducted a study where the authors showed the role of IoT technology in agriculture. The study found various application of IoT in crop and livestock area. For instance, IoT sensors were found that can be used to monitor

crop health, soil moisture, and climate factors. In addition, such sensors can also be used to monitor the health and productivity of livestock.

In another study, Khan et al. (2021) address the role of technology innovation in achieving sustainable food system. The inclusion of advanced technology can help to improve efficiency, reduce waste, and increase resiliency. Moreover, the technology innovation contributes to the ultimate cause of food security through precision agriculture, food waste reduction, and prevention of post-harvest loss.

Kamilaris et al. (2017) found that the application of big data analysis has significant impact on the transformation of agriculture. Big data analysis has widespread application for policymakers to smallholder farmers. Crop monitoring is supported by the application of big data models which help farmers to optimize fertilization and irrigation practices. Moreover, such models are also used for pest and disease management system and agriculture supply chains.

Haneklaus et al. (2016) studied that in Germany the approach to Precision Agriculture is comprise of data acquisition, interpretation, and conversion to enable smart farming services. The initiative has brought Germany advanced solutions like geocoded sampling and mapping, field experimentation, remote sensing, etc.

Beriya (2020) addressed the potential role of data-driven ecosystem in India. The author stated that data interexchange framework between the stakeholders to enable personalised digital services across the agriculture lifecycle is a core component. Overall, the framework promotes data standardization, governance, and interoperability upon which smart services will be built to establish a digital agriculture ecosystem.

In a similar study, Mothkoor et al. (2023) hold the potential of agri stack to transform existing agricultural business processes and services. The implementation of the framework would bring benefits such as financial inclusion and innovation service enablement for all farmers.

Raghavan et al. (2019) addressed the significant benefits of the India Stack on the Indian economy and society. The inclusion of this technology has facilitated citizens to access public services, such as social security and financial inclusion. The technology has also enabled the scaleup of new digital businesses, such as e-commerce and fintech.

Data-Driven Model Review

The establishment of the stack ensure sustainability. Upon establishment, farmers will be able to use climate forecasting tools to plan for his livestock and crops, pest preventive and crop-zoning apps to boost his crop yields. They will also be able to sell their agriculture products to online markets for higher profits. In the event of a worst-case scenario, such as a crop failure, the farmers will be able to access their insurance records through their unique ID. This will allow insurance stakeholders to track the right recipient and acknowledge the claim quickly

and easily. Evidence from India, Estonia and Singapore shows the impact of the stack upon implementation.

India

The inception of India stack began when India was on the verge of economic crisis. While neighbour countries were experiencing rapid economic growth and India was excluded from the pace of high growth. The first use case of India Stack was financial inclusion because only 17% of Indian adults had access to bank account. With one of the largest populations in the world, hundreds of millions of people had no access to the former financial system. Key reason behind the inaccessibility was the high cost of customer verification. In addition, estimated 400 million Indians had no digital identity. Blockage like this led to the development of India Stack, also known as Aadhar project. Through establishment of the Aadhar project a digital identity system was formed to expose citizens to the formal economy. The government of India distributed more than 1 billion Aadhar card, covering more than 90% population. The establishment of digital identity brought down the high cost of e-KYC from $23 to $0.15. The significant reduction facilitated accessibility to financial inclusion for hundreds of Indian citizens (Sanghi, 2021).

After a successful implementation of the Aadhar project, the second layer of India stack was established, known as the Payment layer. Digital transformation an economy is positively correlated with financial inclusion. Therefore, the second layer, Unified Payment Interface (UPI) was rollout developed and implemented across the whole country. With the initial success of Aadhar card, UPI got similar success with a monthly transaction of 2.2 billion, growing over 10% increasing rate. The value of these values stands at $54 billion on a monthly basis. Finally, data layer was developed to facilitate sharing and flow of data between the stakeholders of first and second layer (Sanghi, 2021).

The establishment of India stack has widened the financial inclusion horizon across the nation. The nationwide scaleup of their digital identity, Aadhar card, has significantly lowered the cost of identity verification. Within few years 1.2 billion people, almost 90% of India's population, got access to digital identity with linked bank account. The rapid growth of digital identity has made it easier for the government of India to facilitate financial inclusion across the whole nation (The India Stack Is Revolutionizing Access to Finance - IMF F&D, 2021). The number of digital transactions went up from 21.4 billion in 2016 to 100.2 billion in 2022. The rapid rise showed a growth of almost 400% in six years (Reserve Bank of India - Annual Report, n.d.). Aadhar card digitized India through providing access to formal economy, UPI then developed a railway track to establish an easy and cheap way to digital transaction. Similarly, the final layer connected the dots between the first and second layer to ensure a seamless financial transaction.

Estonia

Estonia's journey in creating e-governance has triggered the digital transformation to increase efficiency in delivering services to its citizens. Estonia's digitization began with the inception of Tiger Leap Program. The first emphasis given through the program was developing network infrastructure and access to internet *(The Estonian Miracle: E-Estonia and the Future of Digital Infrastructure, n.d.*). After a successful implementation of the program, next revolution of digitization emerged around the five pillars:

Digital Identity: State-issued digital identity for all Estonian citizens, also known as e-id, is the first foundational pillar of advancement towards new digitization. Estonians use their digital id for digital transaction, online voting, contract signing, access to information, etc. Approximately, 99% of Estonian citizens have access to digital identity card (The Estonian Miracle: E-Estonia and the Future of Digital Infrastructure, n.d.).

Digital Governance: The pillars of digital governance was built upon on the foundation of three technological initiatives. First initiative was the online voting which allowed Estonia's citizen to cast their votes from anywhere in the world. Second initiative was the e-filing system which is the core of Estonia's judicial system. E-filing system provides data to the judicial information system and ensure a seamless judicial system across the whole country. Lastly, the government led cloud support the security and availability of information systems. Post impact of such digital transformation has led to saving 1400 years of working hours by Estonian government (The Estonian Miracle: E-Estonia and the Future of Digital Infrastructure, n.d.).

Digital Healthcare: The e-health record is integrated with different healthcare providers to established an interoperable ecosystem so that every patient can be monitored and provide tailored healthcare services. The data is stored in a centralized database in a standard format, known as e-patient portal (The Estonian Miracle: E-Estonia and the Future of Digital Infrastructure, n.d.).

Digital Business Infrastructure: Estonia is accelerating rapidly with their country's economic growth. The digital solutions allow businesses to access digital signatures, e-tax, and digital business register that allow entrepreneurs to register business in few minutes (The Estonian Miracle: E-Estonia and the Future of Digital Infrastructure, n.d.).

Cybersecurity: The development Estonia's data infrastructure ensures data privacy and security in a decentralized manner. Through various partnership with private bodies, the government of Estonia has ensured standardized data in an interoperable manner (The Estonian Miracle: E-Estonia and the Future of Digital Infrastructure, n.d.).

The foundation of Estonia's digital transformation has accelerated its technological advancement at speed of light. The development of digital id card and x-road (data sharing platform) have ensured citizens accessibility to government and private services. In a parallel manner, development of documentation like Estonia Information Policy which focus on the openness and interoperability of data has contributed significantly in building the digital ecosystem. Similarly, Estonia's open data law regulate the collection maintenance and sharing of data and public registries in an efficient approach. Apart from the technological development, documentation of policies and laws also contributed significantly to the digital transformation of Estonia (Leosk, 2022).

Singapore

A case study from Singapore emerged during Covid-19 that showed how a case of digital transformation facilitated service delivery to citizens. Scaled up digital tools like Covid-19 recovery grant application provided easy access to all citizens without no physical visits and ensured protection of all livelihoods.

Singapore's journey of digital transformation, known as "The Smart Nation Initiative", started in year 2014. Two core layers, Digital Identity (Singpass) and a government-wide data sharing platform called the API exchange (APEX), are the key drivers behind the Smart Nation Initiative. The initiative is monitored by the Smart Nation and Digital Government Group (SNDGG), which operates from the Prime Minister's Office (PMO) and is resposible for planning and policy functions and the Government Technology Agency (GovTech), functions as the implementation partner (Chan & Chan, 2023).

Singapore's national digital identity, Singpass, operate in the form of mobile application that any citizens of Singapore can use to verify their identity and avail services online. Within the Singpass id remains another feature, Myinfo, that function as a data sharing consent manager between the user and the service provider. Within the jurisdiction of digital identity, a user electronically signs documents and initiate digital transaction. Additional features provided by Singpass include, face verification, digital wallet, and business ID. The post-impact value of Singpass now stands at 350 million financial transactions every year by 4.5 million users with accessibility to more than 2000 public and private services. The capacity to share data in a secured and seamless manner is one key approach to enable digital service delivery. The second core layer of the digital stack played a similar role in empowering public-facing services by enabling data sharing ecosystem between government agencies. When APEX was in process of development there was no government cloud policy or data-sharing laws. As a result, challenges emerged during the activation of data layer (CooperAdam, n.d.)

During the development of both the layers, few key drivers played a significant role behind the establishment. For instance, formulation of required laws and policies during the development of national digital identity contributed as key enablers. The Public Sector (Governance) Act, personal Data Protection act, National Registration Act, and Electronic Transaction Act empowered the legal aspect of the digital identity and data-sharing.

- Public Sector (Governance) Act is responsible for the management of data by government agencies.
- Personal Data Protection Act is responsible for providing standard security to private sectors while sharing personal data.
- National Registration Act is responsible for enabling the national digital identity system upon which Singpass operates.
- Electronic Transaction Act is the "single source of truth" that focuses on electronic transaction through digital signatures and records.

Other than the required acts and laws, development of a technology blueprint was equally necessary for Singapore to design a comprehensive architecture. The first priority was the identifying the necessary architecture and components to enable the ecosystem. Afterwards, additional components including authentication certificate, verification, cloud modality, UX design, security, data protection and privacy was added. To continue the seamless delivery of front-end services, the government of Singapore incorporated support desk for citizens to coordinate external issues, published document publicly, and added demonstration on Singpass (CooperAdam, n.d.).
The successful implementation of Singapore's digital stack was based on multiple factors:

- **Measured approach:** Measured approach taken by Singapore government was one of the key drivers behind successful implementation. They did not rush into implement many components all at once but focused on calculative approach. For instance, their first action was to develop a digital identity which would function as a sign-in to avail government services. Afterwards, the technology evolved and added additional features later on.

- **Prioritizing user experience and understanding needs of all society:** Large investment in improving user experience across the development played a significant role. All developed products and services were initially tested with core stakeholders and group to ensure the sustainability and expansion.

- **Emphasize on use cases:** Focusing on specific sectors that require high level of trust was a key driver in expanding the system to another sector. Similar adoption and implementation approach was taken during the implementation of Singpass and APEX platform.

- **Identification of major data source:** One of the key enablers of Singpass and APEX was identifying major data source from government and private sectors which function as a single "source of truth".

- **Foundational ID:** Single source of identity was one other enabler of successful implementation of the digital stack. Singpass operating as a foundation id complement both citizens and residents living in Singapore. For countries that lack foundational id system face multiple challenges in onboarding and processing citizens or residents.

- **Technology and required human resources:** Adoption of open-source technologies that ensures interoperability is a key element in establishing the whole ecosystem. Parallelly, required human resources are equally crucial to enable the ecosystem.

- **Adoption of technology:** With continuous evolution, Singapore has adopted new technologies as they become relevant with society's need. In this way, they allowed the ecosystem to stay relevant across border and within the country.

Proposed Concept

Recognizing the potential and worldwide evidence of a data-driven approach to transform the agriculture sector, the concept is about establishing data-driven ecosystem to achieve sustainable agriculture in Bangladesh.

The concept of agriculture stack will capacitate Bangladesh's government to leapfrog through the unprecedented use of digital technology and open platforms to transform the government as an enabler and facilitator, providing the infrastructure and tools for farmers and organizations to co-create and deliver services. This approach shifts the focus from a traditional, top-down delivery model, to a more collaborative and participatory model, where the government will be able to take an inclusive approach to solve problems and create value.

The primary objective of the e0agriculture stack falls within the followings:

G - Get services anytime, anywhere

O - Optimize data usage, take once, giveaways

A - Avoid digital silos, ensure interoperability

L - Leverage existing systems, allow the highest level of integration

L - Leave no one behind

The ecosystem is based on the 3 following interconnected layers:

1. Identity Layer:

The Identity Layer provide farmers with a digital identity by setting up unique digital IDs, e-KYC, digital signatures, and authentication. It also ensures that all service providers and financial institutions identify farmers using their unique digital ID, creating a "single point of truth" for farmers' data. Digital Identity is based for multiple purposes including authentication, authorization, and monitoring.

Digital authentication system is the mechanism of creating a trustworthy ecosystem between a service provider and service consumer in digital ecosystem. The use of digital authentication facilitates a service provider to extract information (i.e., socioeconomic) about a user and ensure that right people have the right access to right resources at right time. India Stack's e-authentication system provide confirmation of information to service provider through request interoperability between the service provide and the government body responsible for the database. The request holds the digital ID number to the government body and in return a confirmation is given to the service provider. Another is Digilocker, a cloud-based locker that is linked to Aadhar card. The locker store documents like tax files, driving license, insurance policies, academic certificates, and etc.
The compilation of all these components ensures effective authorization and trust between the user and service provider (India Stack | Identity, n.d.).

Authorization system establish a consent-based environment between the service provider and service consumer to access the consumers database. India Stack's e-KYC uses a biometric of two-layers OTP verification process to provide access to information, monitored by the government body, to the service provider (India Stack | Identity, n.d.). In addition, enhancing

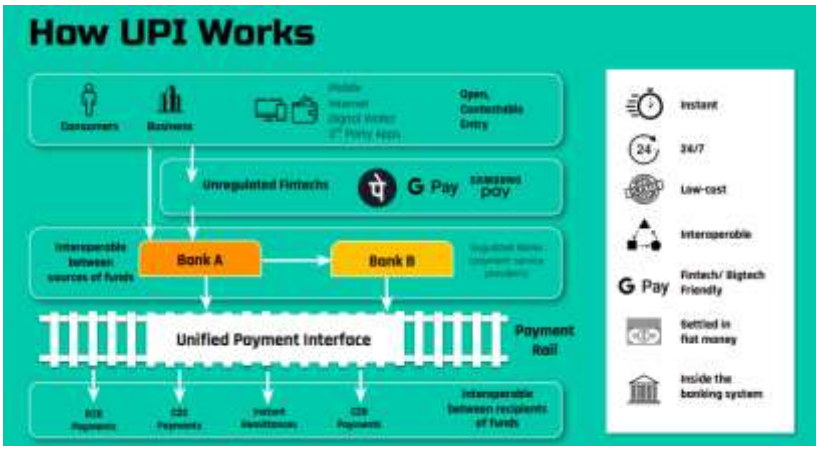

Figure: India's Functional mechanism of Unified Payment Interface (UPI)
Source: (Sanghi, 2021)

features like digital signatures and QR code scan is installed in India's digital identity to ensure a seamless service provision mechanism.

2. Payment Layer

The Payment Layer will facilitate digital transactions through interoperable digital payment systems, making it possible to transact across different types of banking and non-banking financial institutions, and businesses. This layer will be integrated to the farmers' digital ID-linked bank account. The unified system will facilitate digital transactions (i.e., loan disbursement, insurance

claims, etc.) across different types of banking and non-banking financial institutions to provide farmers access to finance.

The Unified Payment Interface is a core layer of India Stack. A UPI is a mobile application that provider an interoperable communication access between user, financial, non-financial, and government to transact money (Ganti, 2023). The system is monitored by the Reserve Bank of India (RBI). The figure below illustrates the functional mechanism of how UPI works in the context of India. At the bottom layer lies the type of financial transaction (i.e., B2B, G2C payments) between users and financial institutions. At the top lies regulated banks responsible

for monitoring of digital transaction. The third layer is the fintech stakeholders connected to the UPI where banking servers are integrated. Through the UPI integration any fintech stakeholder can gain access to consumer and business bank accounts in India and provide targeted service accordingly (Sanghi, 2021).
As a result, a UPI will allow farmers to be included in risk financial coverage, such as crop insurance, to protect from financial losses in the event of a crop failure.

3. Data Layer

The Data Layer ensures the standardization and interoperability of agriculture data within ministries and concerned stakeholders in the agriculture ecosystem. The function of this layer is to activate center-state federated data interactions in a standardized and interoperable format between various public and private stakeholder. An information exchange system will facilitate the authentication, authorization, and transfer of standardized data from different databases or sources and caters to different data requests. The Data Layer facilitate the smooth exchange of data, which will enable government or private sectors to provide digital services to smallholder farmers, enable digital solutions like digital crop calendar, dashboard to track financial inclusion of smallholder farmers, and more.

The data layer of India stack is empowered by the DEPA framework which create an interoperable ecosystem between data owner and data user. DEPA is the core architecture for establishing consent-based data flows across multiple stakeholders while keeping data security, privacy and policies in check (An Introduction to DEPA | DEPA World, 2022).

The DEPA framework follows 6 principles to maintain balance within the ecosystem:

- All institutions need to use same rules and standards (consent) for accessing to data owned by other stakeholder. This facilitates the institutions to become interoperable and share information in a seamless manner.
- The consent given to data user can be revoked anytime by the data provider
- It is necessary to provide consent each time data is shared upon request
- All consent provided to any data request must be recorded for effective tracking and monitoring
- The consent given to any data request must share the purpose and duration of data to the data provider
- The digital consent architecture must ensure all necessary security protocols

The DEPA framework have three party within the ecosystem and each of them have specific set of responsibilities:

- Consent Manager (CM): Responsibilities designed for CM is to acquire any data request from data provider and data consumer.

- Data Provider: The core responsibilities of data provider are to provide consent to any data request if the purpose and usage specification of the data is aligned with data provider's interest. In addition, their other responsibilities include linking with CM to provide consent to data consumer, data preparation, and data sharing.

- Data Consumer: The responsibilities of a data consumer include data fetching, preparation of data purpose to share with the data provider, and linking with CM to request consent to data provider.

Figure: Data Layer
Source: (Actions | DEPA World, 2023)

The concept above has already been implemented in India and with a similar demographic, agriculture stack can be designed and implemented. This will capacitate Bangladesh's government to leapfrog through the unprecedented use of digital solutions and open platforms to transform the government and private sector as an enabler and facilitators, providing the infrastructure and tools for farmers and organizations to co-create and deliver services seamlessly. It aims to provide smallholder farmers access to information, suggestions, and forecasting to increase the production and efficiency of their farms. As a result, they do not have to fall into the trap of debts or leave agriculture due to low production efficiency and profits.

Recommendation

Comprehensive analysis of country-wide approach to establish digital stack has narrowed down the few recommendations on building an agriculture stack.

Country	Layers	Approach to establish digital Stack
India	▪ Identity Layer ▪ Payment layer ▪ Data Lyer	▪ Prioritization of use case (financial inclusion) ▪ Formation of regulatory body to monitor and implement different layers ▪ Establishment of layers as per serial a. Identity b. Payment c. Data ▪ Establishment and update of act and policies relevant to the stack
Estonia	▪ Identity Layer ▪ Data Layer	▪ Establishment of Digital stack revolving around 5 layers a. Digital Identity b. Digital Governance c. Digital Healthcare d. Digital Business Infrastructure e. Cybersecurity
Singapore	▪ Identity Layer ▪ Data Layer	▪ Development of Identity ▪ Identification of major data sources ▪ Formulation of relevant policies, act, and laws ▪ Measured approach to develop a simple use case ▪ Pilot testing before scalability

Table 1: Data-Driven Model Approach Analysis

The table above illustrates a clear analysis of the approach and acts taken by respective countries while developing digital stack in their nation. Based on the above approach, similar approach is recommended in case for Bangladesh.

angladesh has multiple identity established decades ago and continues to function in a siloed manner. Digital Identity like NID, BRN need integration to develop into one foundation ID system. Under the single foundational ID, use case specific functional ID can be developed within the agriculture ecosystem. Bangladesh demographic status and cultural exposure is very similar to India. Therefore, the agriculture stack must incorporate the payment layer as an extra layer.

Country	Legal Framework	Status of Bangladesh
India	Aadhaar Act, 2016	Bangladesh currently has no act on digital identity system. However, there are several provisions that shed light on the use of digital identity. Such as ICT Act, 2005
	Information Technology Act, 2000	ICT Act 2006
	Payments and Settlements Systems Act, 2008	Bangladesh Payment and Settlement System Regulations-2014
	Data Empowerment and Protection Architecture (DEPA) Framework	Bangladesh currently has no data sharing architecture and framework
Estonia	Estonia Information Policy	No Information Policy
	Public Information Act	Right to Information Act, 2009
	Estonia Interoperability Framework	No Interoperability Framework
Singapore	Public Sector (Governance) Act	A draft act is on process of preparation, The Data Protection Act 2022
	Personal Data Protection Act	A draft act is on process of preparation, The Data Protection Act 2022
	National Registration Act	No National Registration Act
	Electronic Transaction Act	No Electronic Registration Act

Table 2: Analysis of Legal Framework of Referred countries to empower the data-driven models

The above table shows the provisions required to establish the agriculture stack. The respective countries have developed the acts and policies in a parallel manner. Therefore, it is highly recommended that required provision are in act of development in parallel with technology development. Also, one specific use case from government end needs to be piloted with close group and key stakeholders to ensure sustainability of the agriculture stack. Moreover, relevant guidelines, framework, updates in information act and policy formulation are also recommended for Bangladesh to enable digital services in agriculture sector.

Apart from the above recommendation, two extra layers can be added in context of Bangladesh, Access Layer and Service layer. According to a study, more than half of smallholder farmers have access to basic phone instead of smartphone. Smallholder farmers without smartphone lack the awareness or urgency to buy one. Majority of the study participants spend less than $3.48 per month on data or talk time. In addition, lack of education among the farmers makes it tough to access the full potential of smartphones (Feed the Future, 2022). Therefore, these data clearly imply that physical accessibility to highly required in Bangladesh to enable the full potential of digital services.

The access layer will function as the accessibility portal to government services, digital resources, access to information, finance and market, making them available, reachable, and affordable to farmers. The Government of Bangladesh is investing in expanding internet access and digital infrastructure in rural areas to ensure that farmers have access to digital services. Moreover, Bangladesh has a wide range of communication mediums available for last-mile farmers. Already established 9000 Union Digital Centers, National Call centers such as 333 are facilitating the farmers to access information, inputs, and resources. Moreover, the government is investing in expanding internet access and digital infrastructure in rural areas to ensure that farmers have access to digital services.

Bangladesh is a country with rapidly growing economy. The statistical rate of service providers is increasing at a parallel speed. To enable the scalability of digital services, the extra layer will share open access points to relevant databases. Therefore, the Services Layer will provide access to digital services through open online platforms and physical and virtual access points. It enables the interoperability of services across multiple departments, resulting in farmer-centric, unified delivery of essential services at key moments of life. The layer also enables the building of additional layers to unlock new use cases and types of services, such as open networks for credit and insurance. The layer will also unlock new use cases and types of services, such as crop-zoning applications, weather forecasting, etc, pest prevention, etc. The government has already introduced several digital services for farmers, including weather and pest alerts, crop insurance, and market price information.

Conclusion

The establishment of the Agriculture Stack will ensure interoperability to design demand-driven services oriented around farmers' needs, rather than the organizational structure of government. The primary outcomes will achieve or significantly contribute to the followings:

- Enablement of integrated service delivery platforms and smart solutions, from the public and private sectors, to enhance agri production, access to finance, information, and market
- Data-driven decision-making tools for policy-makers to make nationwide quick decisions on enabling farmers' access to information and resources to increase crop production
- Data-driven tools for smallholder farmers to forecast weather or crop-related challenges
- Access to finance (i.e., loan, crop/livestock insurance, etc.) to prevent farmers from going into debt
- Reduction of Time, Cost, and Visits for smallholder farmers and relevant stakeholders
- Seamless coordination across concerned ministries, private organizations, development organizations, and volunteers

Overall, the agriculture stack is an interconnected yet independent “platforms” that work together towards general-purpose tasks. The stack is a way of creating and delivering value to all farmers in the digital age.

Looking into the rapid and sustainable growth stories of India and Estonia, Bangladesh is well positioned to leverage the potential of the Agriculture Stack. The development of the proposed concept will lead to potential expansion opportunities:

- Onboarding of all government service;
- Building digital services to unlock new application scenarios (e.g., payments, credit, healthcare, talent, etc.);
- Allow access to private players to accelerate the development of standardized service applications.

So, the inclusion of the proposed solution in Bangladesh’s agriculture sector will transform the life of a smallholder farmer named Shohag who will be able to claim insurance for his livestock and crop from the government. By combining Shohag’s unique national identification number with digital signatures and e-KYC services, government officials will be able to access his insurance records anytime, anywhere, and acknowledge the claim accordingly. Moreover, the

Smart Agriculture Stack will help Shohag to access various government services related to insurance, credit, etc.

References

Beriya, A. (2022). India Digital Ecosystem of Agriculture and Agristack: An Initial Assessment (No. 68). ICT India Working Paper.

Farooq, M. S., Riaz, S., Abid, A., Umer, T., & Zikria, Y. B. (2020). Role of IoT technology in agriculture: A systematic literature review. Electronics, 9(2), 319.

Haneklaus, S., Lilienthal, H., & Schnug, E. (2016, July). 25 years Precision Agriculture in Germany–a retrospective. In 13th International Conference on Precision Agriculture.

Imdad, M. P. (2021, February 11). Revitalising Bangladesh's agriculture sector. *The Daily Star*.

Kamilaris, A., Kartakoullis, A., & Prenafeta-Boldú, F. X. (2017). A review on the practice of big data analysis in agriculture. *Computers and Electronics in Agriculture*, *143*, 23-37.

Khan, N., Ray, R. L., Kassem, H. S., Hussain, S., Zhang, S., Khayyam, M., ... & Asongu, S. A. (2021). Potential role of technology innovation in transformation of sustainable food systems: A review. Agriculture, 11(10), 984.

Oecd. (n.d.). Case study 8: Estonia e-government and the creation of a comprehensive data infrastructure for public services and agriculture policies implementation. OECD iLibrary. https://www.oecd-ilibrary.org/agriculture-and-food/digital-opportunities-for-better-agricultural-policies_510a82b5-en

Raghavan, V., Jain, S., & Varma, P. (2019). India stack---digital infrastructure as public good. *Communications of the ACM*, *62*(11), 76-81.

Reserve Bank of India - Annual Report. (n.d.). https://m.rbi.org.in/Scripts/AnnualReportPublications.aspx?Id=1322

Sajid, E. (2020, January 5). Irrigation in Barind tract to get costly. *The Business Standard*.

Smallholders Need Intensive Care (2020) The Financial Express. Available at: https://thefinancialexpress.com.bd/views/views/smallholders-need-intensive-care-1609340481

The India Stack is Revolutionizing Access to Finance - IMF F&D. (2021, July 27). https://www.imf.org/external/pubs/ft/fandd/2021/07/india-stack-financial-access-and-digital-inclusion.htm

World Bank. (2018). The role of digital identification in agriculture: Emerging applications. Washington, DC: World Bank. Retrieved September 30, 2023, from https://documents1.worldbank.org/curated/en/655951545382527665/pdf/The-Role-of-Digital-Identification-in-Agriculture-Emerging-Applications.pdf

45 years of Agriculture Statistics of Major Crops (Aus, Amon, Boro, Jute, Potato& Wheat). (2018). Retrieved from https://bbs.portal.gov.bd/site/page/453af260-6aea-4331-b4a5-7b66fe63ba61/-

Henke, N., Bughin, J., Chui, M., Manyika, J., Saleh, T., Wiseman, B., & Sethupathy, G. (2016, December 7). The age of analytics: Competing in a data-driven world. McKinsey & Company. https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-age-of-analytics-competing-in-a-data-driven-world

Data-Driven Food Systems for Crisis Resiliency. (2020, September). In World Economic Forum . World Economic Forum. Retrieved November 5, 2023, from https://www3.weforum.org/docs/Data_Driven_Food_Systems_for_Crisis_Resiliency.pdf

Shaikh. (2008, November 15). Bangladesh agriculture: Challenges ahead. The Daily Star. Retrieved November 5, 2023, from https://www.thedailystar.net/news-detail-63295

Actions | DEPA World. (2023, August 10). https://depa.world/learn/about-depa/depa-actions

An Introduction to DEPA | DEPA World. (2022, March 9). https://depa.world/learn/about-depa/an-introduction-to-depa

A., & Sanghi, R. (2021, January 14). The Internet Country. By Aaryaman.Vir and Rahul Sanghi. https://tigerfeathers.substack.com/p/the-internet-country

Ganti, A. (2023, June 21). Unified Payments Interface (UPI): Definition and How It Works. Investopedia. https://www.investopedia.com/terms/u/unified-payment-interface-upi.asp

India Stack | Identity. (n.d.). https://indiastack.org/identity.html

The Estonian Miracle: E-Estonia and the Future of Digital Infrastructure. (n.d.). sps.nyu.edu. https://www.sps.nyu.edu/homepage/metaverse/metaverse-blog/the-estonian-miracle-e-estonia-and-the-future-of-digital-infrastructure.html

Leosk, N. (2022, October 26). Estonian Case – The development and promotion of Digital Public Infrastructures. ORF. https://www.orfonline.org/expert-speak/development-and-promotion-of-digital-public-infrastructures/

CooperAdam, K. D. C. H. (n.d.). National Digital Identity and Government Data Sharing in Singapore : A Case Study of Singpass and APEX. World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099300010212228518/p171592179b3e5df14cae14ed71a1631d5663205bf94

Chan, C. Z. Q. C. H., & Chan, C. Z. Q. C. H. (2023, October 2). How Singapore's national digital identity and government digital data sharing platform fosters inclusion and resilience. World Bank Blogs. https://blogs.worldbank.org/digital-development/how-singapores-national-digital-identity-and-government-digital-data-sharing

Feed the Future. (2022, March 1). Digital Insights on Agriculture in Bangladesh. In Digital Frontiers. Digital Frontiers. Retrieved November 13, 2023, from https://www.digitalfrontiersdai.com/resources/digital-insights-on-agriculture-in-bangladesh/