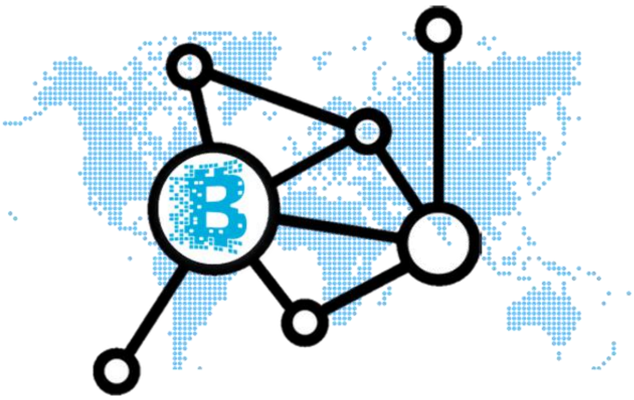

APPLICATION OF BLOCKCHAIN, IOT AND AI FOR FOOD SUPPLY CHAIN, A CONCEPT NOTES BY GRUS & GRADE

A Concept note by Grus & Grade

ABSTRACT

A detailed concept notes on application of blockchain, IoT and AI for end-to-end traceability of Agri commodities and food.

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The summary of the strategic recommendations for digitalization of entire value chain has been explained in figure 1 below:

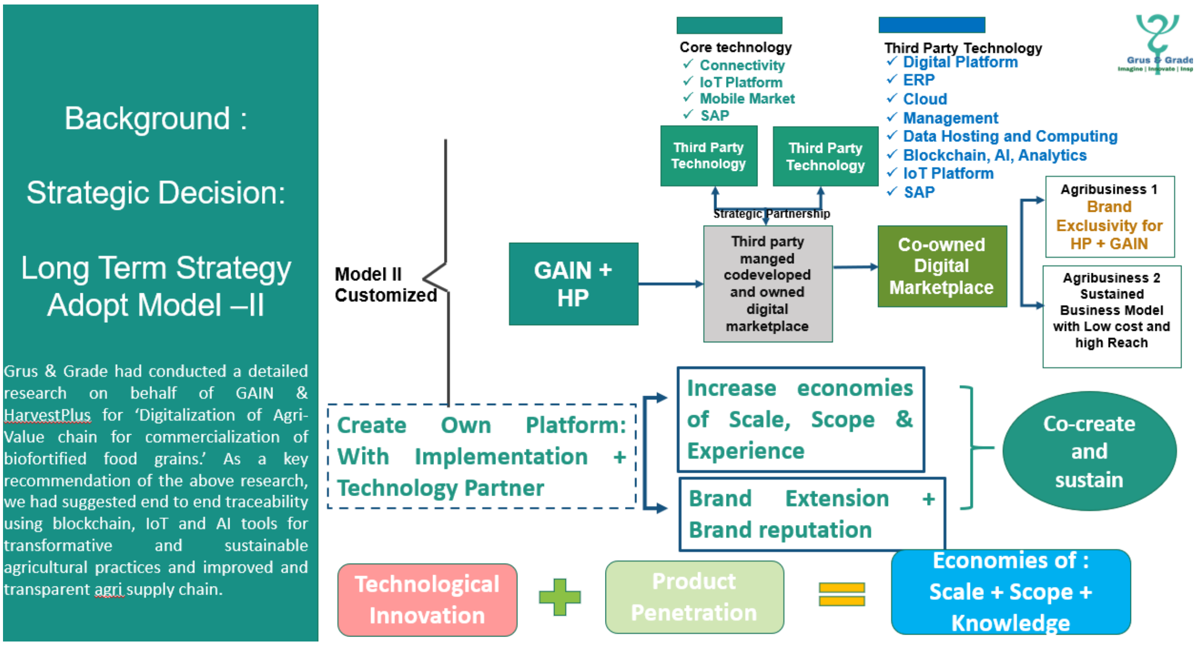


Figure 1: G & G strategic long-term recommendation to GAIN & HarvestPlus for Digitalization of Agri-Value Chain for commercialization of biofortified food grains

To solve the above problems, Grus & Grade proposes an end-to-end cloud-based enterprise level solution through a mobile app enabled with traceability based on blockchain technology, for storage and query of product information in supply chain of agricultural products. The proposed model envisages the application of image processing technologies, field sensor technologies, remote sensing, GPS tracking and application of IoE (Internet of Enterprises).

An end-to-end enterprise level project that would be implemented in collaboration with Harvest Plus in the pilot phase over a small sample to evaluate acceptance of the model in different cultural setups of value chain players, quantification of benefits or value creation and how this value can be distributed across the value chain. We also wish to evaluate sustainability and scalability of the project for commercialization of biofortified food grains. The pilot project will also evaluate the long-term benefits for Harvest Plus in global context.

GAP Analysis in digitalization process and capabilities of existing market Players

Grus & Grade research team evaluated the existing agrotech companies and startups in India and found the following gaps in the claim of these market players:

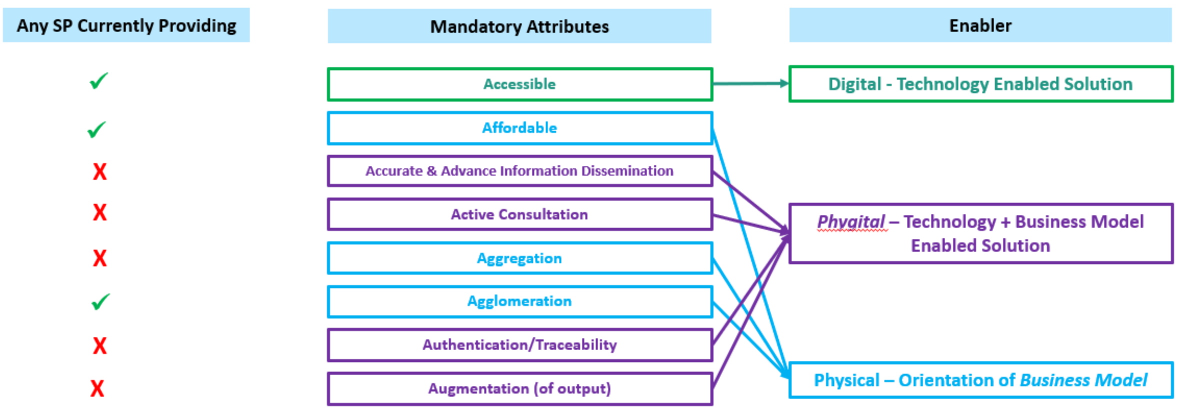
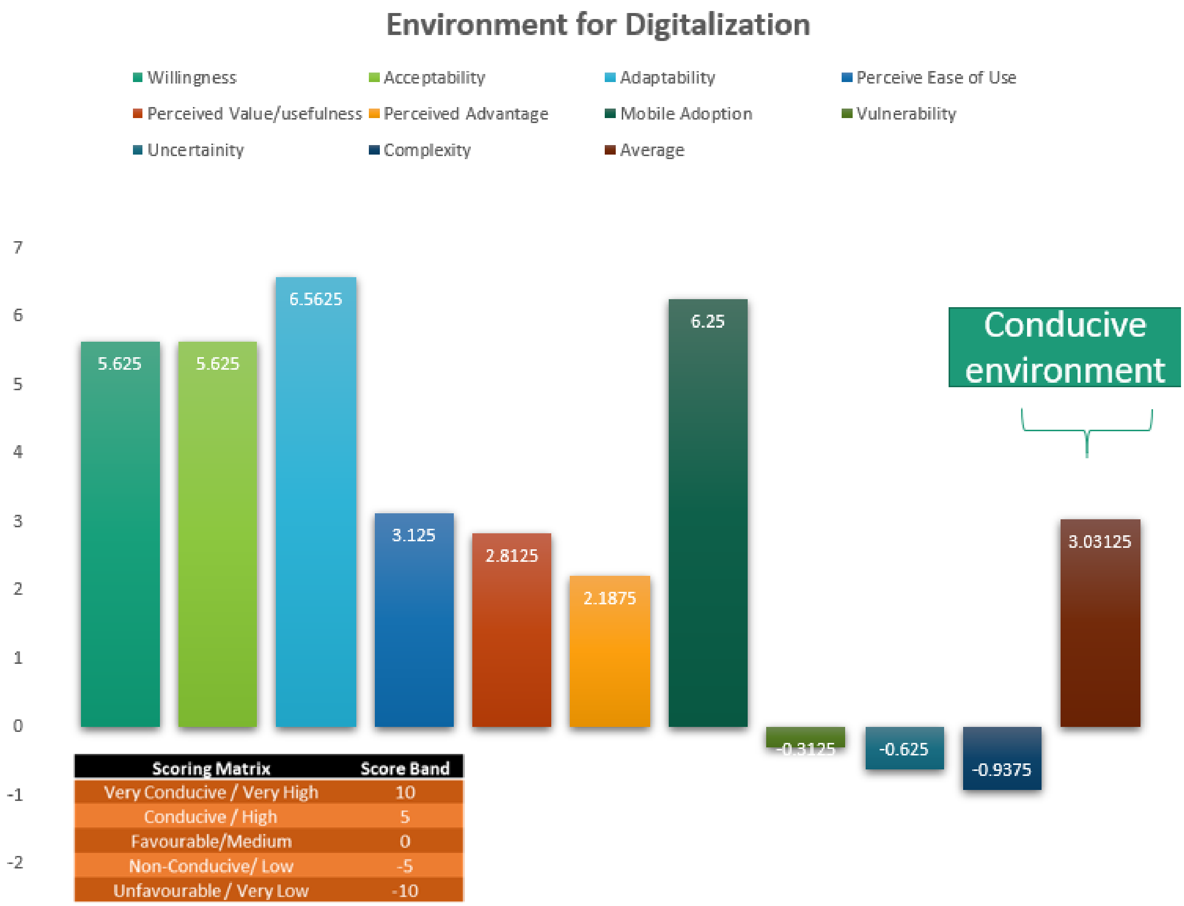


Figure 2: Gaps in existing digital service providers vs mandatory attributes for value creation, Source-Grus & Grade

- From the outside, digital marketplaces appeared to be solutions which would be highly technical in nature.
- As we can see in the figure 2 above, it is more about *how you design* the solution rather than what technology you design it on.
- Almost all service providers have a business model which is valuation oriented – no customer orientation. Hence, farmers are required to adapt to *whatever* the platform offers.
- Currently, there are hardly 1-2 service providers addressing farming related challenges through technology (pre-farming and during-farming domains), but then those platforms do not have a marketplace.
- All the marketplaces fail to bring in genuine differentiation based on traceability. All are concerned about growth of transactions and users – again valuation orientation.

Barriers in adoption and perceived willingness for adoption of technology by farmers:

A recent research study conducted by Grus & Grade showed that despite a positive willingness of the farmers, millers, and processors to adopt the digitalization of Agri value chain (refer figure 3), the acceptability, adoptability and adaptability of technology by the small holder farmers is fraught with the following challenges:



Scoring Matrix	Score Band
Very Conducive / Very High	10
Conducive / High	5
Favourable/Medium	0
Non-Conducive/ Low	-5
Unfavourable / Very Low	-10

Figure 3: Perceived willingness of agri value chain players to adopt digitalization, source: Grus & Grade

1. There is quantifiable value data to support the argument that the digitalization of agri-value chain creates value and how the value created can be redistributed among the value chain players, especially the seed companies, farmers, millers and food processors.
2. In the absence of any numerical data for value creation and distribution, digitalization process attracts political and social unrest including protests by farmers, intermediaries, civil society and political parties.
3. Resistance to change, perceived complexity of using digital technology by small holder farmers and cultural and behavioural orthodoxy are the biggest entry barriers of mobile enabled digital solutions in rural areas.

Grus & Grade Research on value creation and its measurement due to digitalization of Agri-value chain:

Grus & Grade's hypothesis driven approach adopted the following hypothesis before proposing end-to-end enterprise level digitalization tools through application of blockchain technology, artificial intelligence, Internet of Enterprise, GPS tracking, and sensor-based technology:

1. End-to-end traceability solution using blockchain technology will ensure trust among the agri-value chain players, enable traceability of quality and quantity of biofortified food grains to the millers and processors, and create an incremental delta at each node of the entire value chain. The incremental value created can be redistributed among the stakeholders for creating a self-sustainable model.
2. Application of artificial intelligence technology (image processing) can ensure predictability of production (quantity and time) for processors (demand and supply forecasting and planning.
3. Real time monitoring of pre-harvest and post-harvest activities by different stakeholders in agri value chain using *Internet of Enterprises* can reduce food wastage, transportation cost and time.
4. Weather forecasting technology on real time basis can reduce the risk for farmers, while it can also help in managing resources including power, fuel and water (thus positive environmental effect)
5. Real-time monitoring, evaluation, and assessment of land under cultivation, predictability of quantity and quality of supply before and at the time of harvesting season using mobile app image processing and geo-tagging-based technologies.
6. Electrochemical sensors can be integrated onto one chip as a sensor array to provide a feasible approach of multi-targets simultaneous detection. Thus, an automated multi target rapid detection of soil nutrients can be ensured using *KISS (Keep it Simple and Stupid)* principle.
7. Immediate settlement of dues to farmers, reduction in layers of intermediaries and real time access to information and transparency will have long term positive impact to overcome cultural and perceptual bias against digitalization of agri-value chain.

The adoption of the above-mentioned technological solutions in digitalization strategies can create an incremental value in each node of the entire food value chain as illustrated in table below:

Variables in value chain node	Existing Process	Proposed Process	Reasons for creation of Delta	Numerical Delta (Value Creation)
Seed Procurement	Lack of traceability between Seed Company,	QR code enabled blockchain solutions over Hyperledger	Increase in demand for seed companies (Volume)	$\delta^p = \pi\,(\delta Q \times \delta P)$ (Value created due to procurement) =

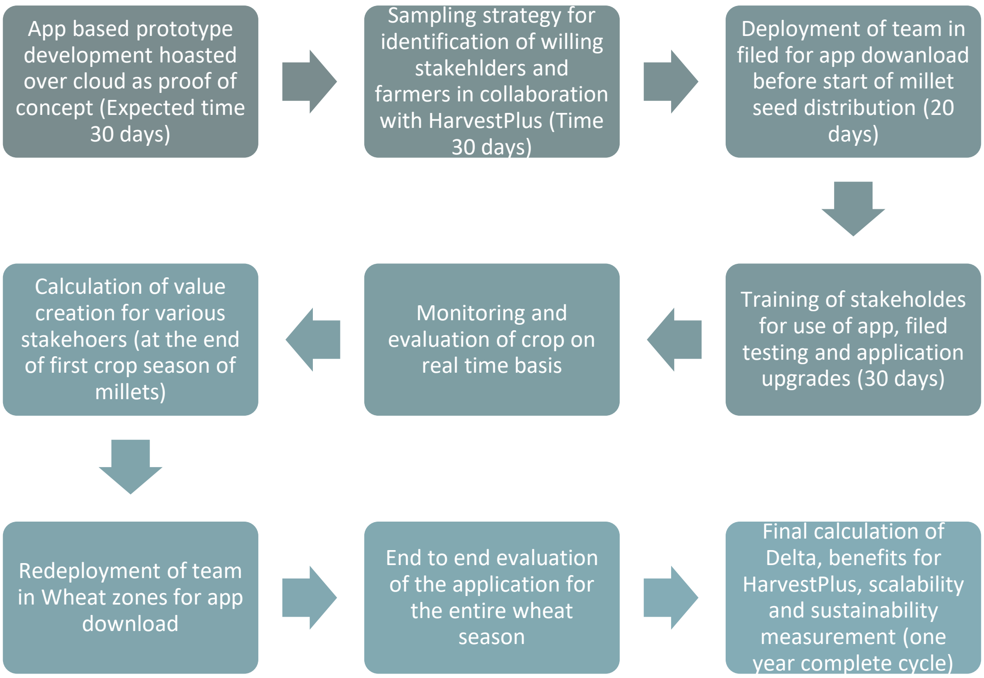
	Distributors and Farmers	fabric for smart contract	Better price to distributors	sum product of change in supply of seeds and price appreciation
Farm cultivation	No specific demarcation of land under cultivation for biofortified crops	Geo Tagging of Filed using IoT devices and regular monitoring of crop using image processing technology through mobile APP	Traceability of quality and quantity of crop under cultivation Continuous monitoring and feedback to farmers, aggregators	$\delta^{C} = \pi\,(\delta Q \times \delta P) + (IC/i)\sum\Delta\,(i2 - i1) + (LV/L)\sum\Delta(l2 - l1)$ (summation in net increase in volume and price, information flow and reduction in crop loss or wastage)
Harvesting and Transportation	Cost burden based on variability of distance, shared by farmers and millers. Unpredictability in scheduling, optimum route mapping, aggregating, etc.	Planned schedules for harvesting using AI technology (image processing, GPS tagging and route planning)	Cost efficiency due scheduling of crop harvest, route optimization for transportation and real time access to information by farmers, transporters, and millers	$\delta^{H\&T} = TC/D)(\sum\Delta\,(d1 - d2) + (VI/T)\sum\Delta(t2 - t1)$ Summation of increase in value created due to optimization of route and time
Millers and Food Processors	Food grains are procured from Mandi (inefficient mechanism with no record of traceability). Higher transaction cost due to manual process, commission agent dominance, etc.	Real time access to information about grain production, land under cultivation, harvesting, transportation and aggregation. (dashboard for aggregators) Complete traceability for quality and quantity using blockchain	Reduction in arbitrage cost Reduction in level of intermediaries Reduction in cost of fortification Reduction in wastage Cost efficiency, time efficiency and planning	$\delta^{MFP} = AV/AC)(\sum\Delta\,(ac1 - ac2) + \left(\frac{VI}{I}\right)\sum\Delta(I2 - I1) + \left(\frac{VF}{F}\right)\sum\Delta(F2 - F1) + (LV/L)\sum\Delta(l2 - l1)$ Summation of increase in value due to reduction in arbitrage cost, intermediary cost, fortification cost, wastage, and planning.

Scope of Work for the first phase of project development:

1. An easy-to-use mobile app having easy to use interface for seed companies, distributors, farmers, millers, processors, food companies.
2. End to end traceability solution through blockchain technology.
3. Image processing and geo tagging enabled mobile app for crop monitoring, area mapping, planning, scheduling and prediction of yield.
4. Real time access to data by all stakeholders through cloud-based architecture.
5. Pilot implementation over a sample of 1000 farmers in the first phase (for two crops)
6. Continuous handholding, training, monitoring and evaluations of project outcome for one year
7. Base-line survey for existing cost and value without use of app solution (using the mobile app)
8. Mid-line survey for measuring outcome of the project objectives and hypothesis testing (through app only)
9. End-line survey to measure the value creation and how the incremental value can be redistributed for commercialization of biofortified food grains.
10. Post success of first phase (pilot phase), full scale launch with improved version and added features for complete roll out and scaling up of operations.

Grus & Grade Proposal for end-to-end digitalization of process flow using AI, Blockchain and IoT technologies:

Project Development and implementation process flow for pilot stage (Phase-I):



After completion of one crop cycle for both millets and wheat, the value creation will be measured with an immense potential for commercialization of biofortified food grains. Grus & Grade intends to be a long-term associate and aggrotech partner with Harvest Plus in process innovation, technology innovation, implementation, scalability, and sustainability of the application in short and long run.

Grus & Grade Proposed Technological Solutions, Design & Architecture, and application framework.

1. Blockchain Technology for end-to-end traceability on real time basis:

Grus & Grade proposes an end-to-end cloud-based enterprise level solution through a mobile app enabled with traceability based on blockchain technology, for storage and query of product information in supply chain of agricultural products.

Leveraging the characteristics of decentralization, tamper-proof and traceability of blockchain technology, the transparency and credibility of traceability information increased. A dual storage structure of ''database + blockchain'' on-chain and off-chain traceability information is constructed to reduce load pressure of the chain and realize efficient information query. Blockchain technology combined with cryptography is proposed to realize the safe sharing of private information in the blockchain network. In addition, we design a reputation-based smart contract to incentivize network nodes to upload traceability data. Furthermore, we provide performance analysis and practical application, the results show that our system improves the query efficiency and the security of private information, guarantees the authenticity and reliability of data in supply chain management, and meets actual application requirements.

In order to improve biofortified food tracing efficiency and reduce food grain tracking efficiency and reduce tracking and monitoring cost, analysing existing biofortified food grain, seed procurement, supply, farm production, testing, location, transportation, grading, sorting, processing and distribution and sale, a one enterprise traceability system by RFID/QR Code technology, Image Processing Technology, Artificial Intelligence and Blockchain technologies are proposed using Mobile Phone and Cloud infrastructure as key enablers.

Emphasis on an analysis of the RFID system, middleware, and applications such as mobile phone or wireless PDA of internet of things. The final analysis of the network on the Internet based on the Grus & Grade biofortified enterprise traceability system integrated approach. The system provides the details about biofortified food information for the consumers and a good operation platform for biofortified production management and biofortified quality safety monitoring. Application results show that the warehouse, millers, and food processors have a significant effect in improving the tracing efficiency and reducing the tracking and monitoring cost.

The main Components of Blockchain infrastructure proposed by Grus & Grade Include:

1. *Understanding of the present shortcoming of current agricultural product traceability and proposed solution.*
2. *Application of Blockchain, IoT and AI technology to enhance the traceability of agricultural product on real time basis. The proposed solution eliminates heavy load, slow query speed and data privacy protection through blockchain technology. The detailed design of the on-chain and off-chain storage structure and privacy data protection will be key part of the enterprise solution by Grus & Grade.*
3. *We build blockchain environment based on Hyperledger Fabric and use python to develop and implement traceability. Application of TensorFlow for image processing and NLPs, Angular, GUI & Github technological framework for simpler and user-friendly user interface and user experience.*

Design of the traceability system

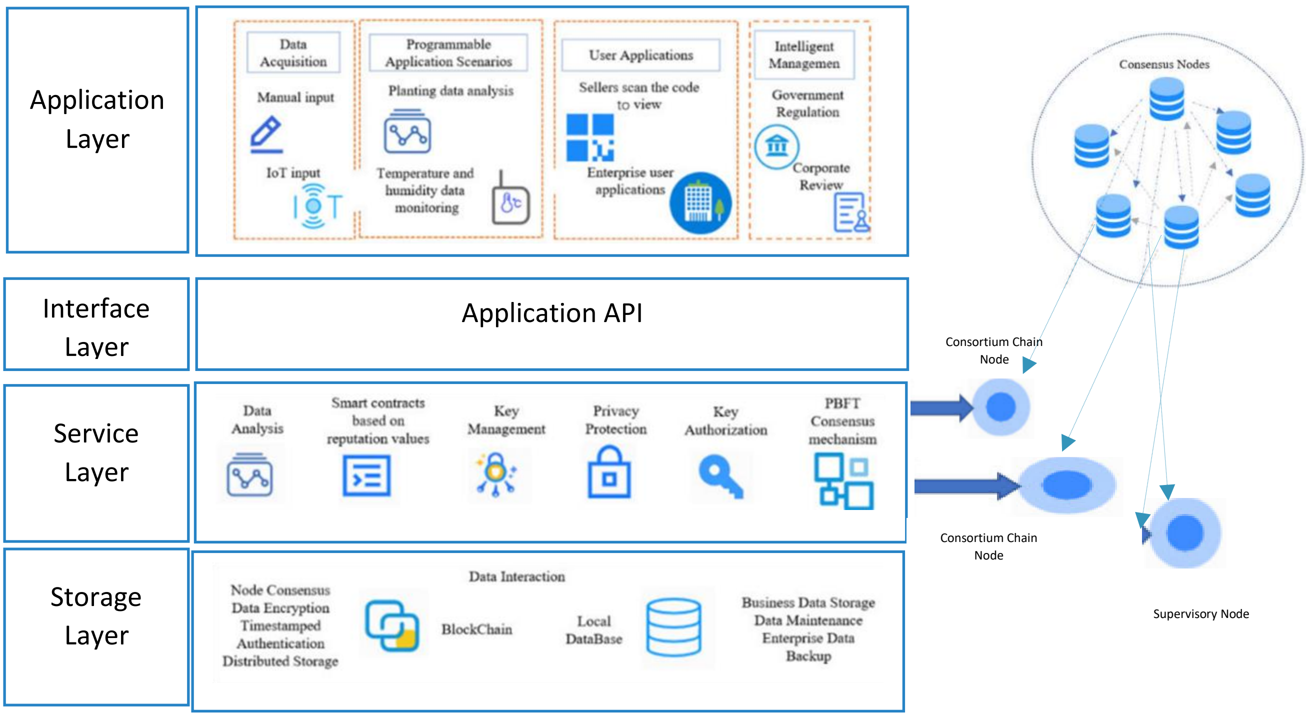


Figure 4: Blockchain Based Traceability Solution Architecture, source Grus & Grade.

End to End Traceability Architecture Design by Grus & Grade:

Seed Company Node 1 — QR/RFID Enabled Block - Smart Contract

- Seed Company Provides detailed seed / crop composition, nutrition content, date of production, batch, size, etc.
- First node and smart contract between seed company and seed distributors (labeling and packaging ensured).
- First layer of traceability

Seed Distributors Node 2 — A smart contract between Distributors to Retailers

- Second block created through smart contract between distributor and retailers.

Retailer Node 3 — Retailers provide seed to farmers, created another smart contract in Hyper ledger Fabric

- Third block is created, user or farmer data mapped on distributed ledger

Farmer Node 4 — Farmer takes image of farm while using HP seeds

- Seed quantity supplied is recorded
- approximation of cultivated area per unit of seed is recorded
- estimated production per unit of seed cropped vs area of land needed recorded
- the data is cross talled by claim made by farmers
- Culitvated crop is tracked for growth and production using mobile, Image Processing and sensors on filed

Harvester & Transporter sub-Node — Final Agri Commodities transported to millers through transporters

- Image mapping using Google Map and mobile image tracked
- QR code on gunny packs for tracceability by millers

Food Processor / Miller Node 5 — Smart Contract between farmer and miller

- Millers can aggregate at better price, quantitity and quality using tracebility
- better price to farmers
- Prediction about supply from farmers
- Prediction of timings for procurement
- Staging for processing on real time basis

Food Company and Distribution Node 6 — Final Node and smart contract for food processors and food company

- Consumers can scan QR code to know about origin, variety, nutrition, chemicals etc.

Figure 5: Farm to Fork Blockchain Architecture, Source : Grus & Grade

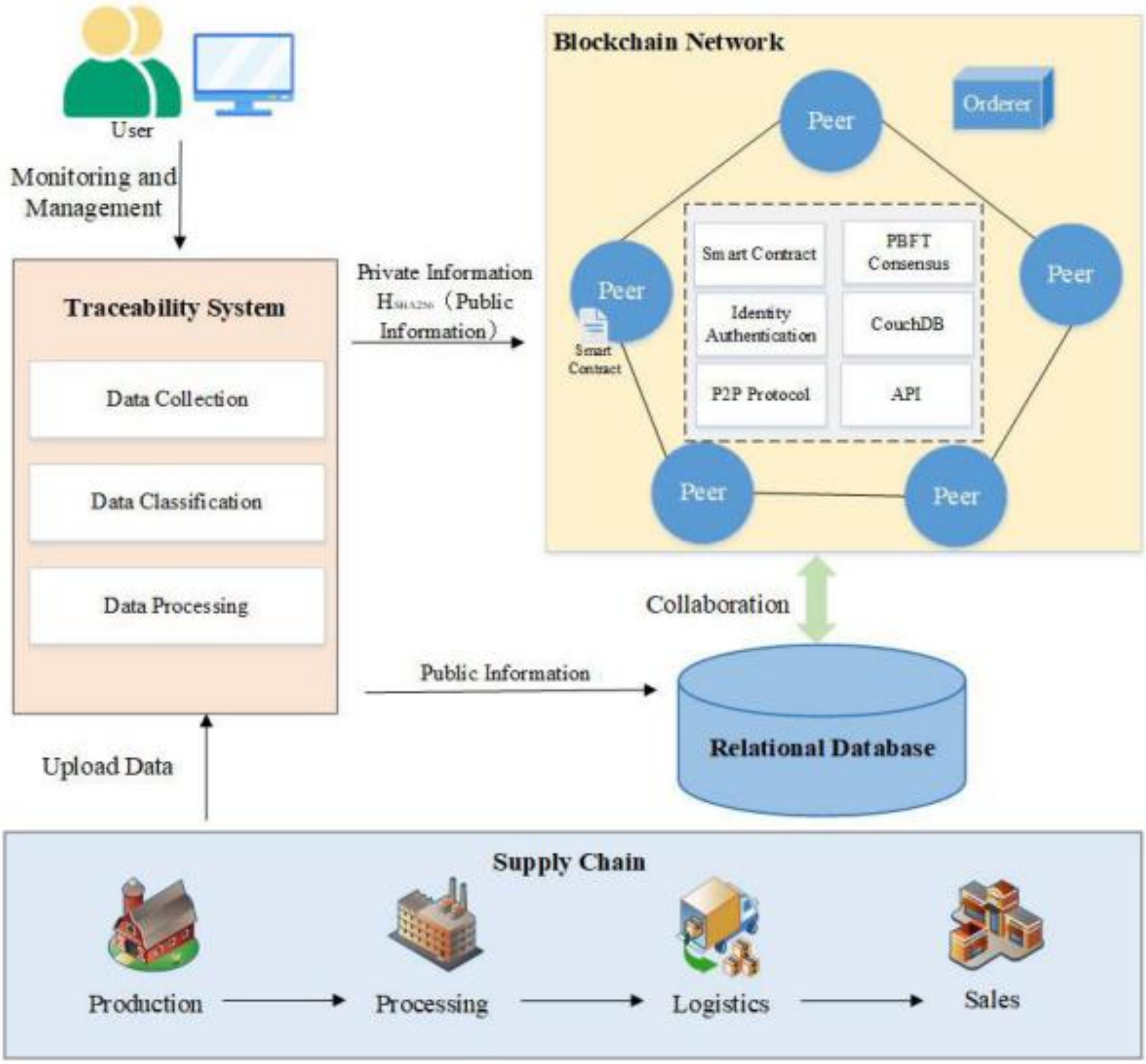


Figure 6: On-Chain and off Chain data collaboration storage, Grus & Grade

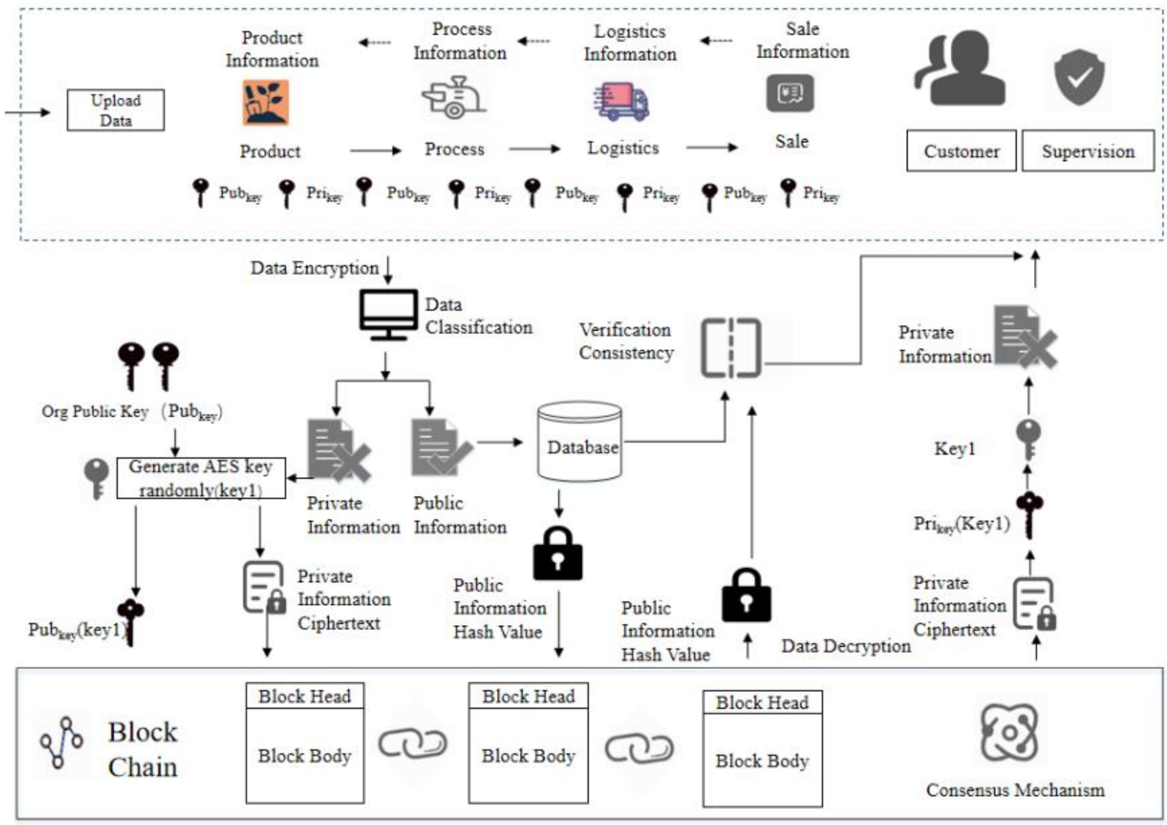


Figure 7: Traceability Information privacy protection data flow diagram, Gus & Grade

Smart Contract Interface

Contract Business Logic	Interface Definition	Interface Description
Upload Traceability Data	*Put Trace data*	Upload hash value of traceability data to blockchain
Query Traceability data	*Query Trace data*	Query hash value of traceability data from the blockchain
Initiate reputation value	*InitReputation*	Initiate reputation value when node joins alliance
Allocate reputation value	*GetReputation*	Grant reputation value to node
Query reputation value	*QueryReputation*	Query Reputation value of node.

Figure 8: Source: Grus & Grade

2. **Crop Monitoring and forecasting using image processing technology, application of Artificial Intelligence tools and IoT sensors:**

Application of AI and IOT in farm domain:

1. **Automated work process** - With the adoption of artificial intelligence, the scope of manual input shall decrease substantially in agriculture. Our image processing tools via app will simplify the entire process of identification of the crop water requirement and various diseases in farm plants. The IOT app, will be able to show the collected data from to the farmers on their phones. This automated work processes will empower them to make informed decisions in a much lesser time.

2. **Effective soil data collection** – Our application in second phase of the development will be using AI-based soil sensors, valves and flow meters to collect static and dynamic data on the soil. The complex algorithms will analyse the collected data to regulate the flow of water to the crops on the farmlands.
3. **Monitoring crop growth** - AI remains relevant throughout the agricultural process. From selecting the best seeds to predicting the appropriate time for planting and harvesting, AI based app will help farmers to determine a maximum return on crops. While AI sensors will monitor crops and soils, its complex algorithms analyse the water need. This means AI stands important for effective water management as well. The proposed IOT app will bring smart agricultural practices in the palm of farmers thereby leading them to higher revenue generation.
4. **Accurate weather prediction leading to better crop management** - Artificial Intelligence and Machine Learning are effective in weather forecasting and climatic disaster prediction. Therefore, the introduction of these technologies in precision farming can help farmers to analyse the steps to take to save their crops from any future damage. Furthermore, taking a cue from these forecasts, they can decide on which kind of crop should be planted and in which season. Accurate forecasting leads to better crop management.
5. **Increased ROI** - The application of AI in agriculture is divided into two major categories of predictive analysis and crop and soil monitoring. Farmers will be better acquainted with pest and disease predictions, various parameters of soil management, weather forecasts, and scientific water management. On top of that, IOT backed agricultural practices through mobile app will have added convenience to the works of farmers. These combined factors will not only result in better crop production cycle, but also usher maximum Return on Investment on crop yields for the farmers.

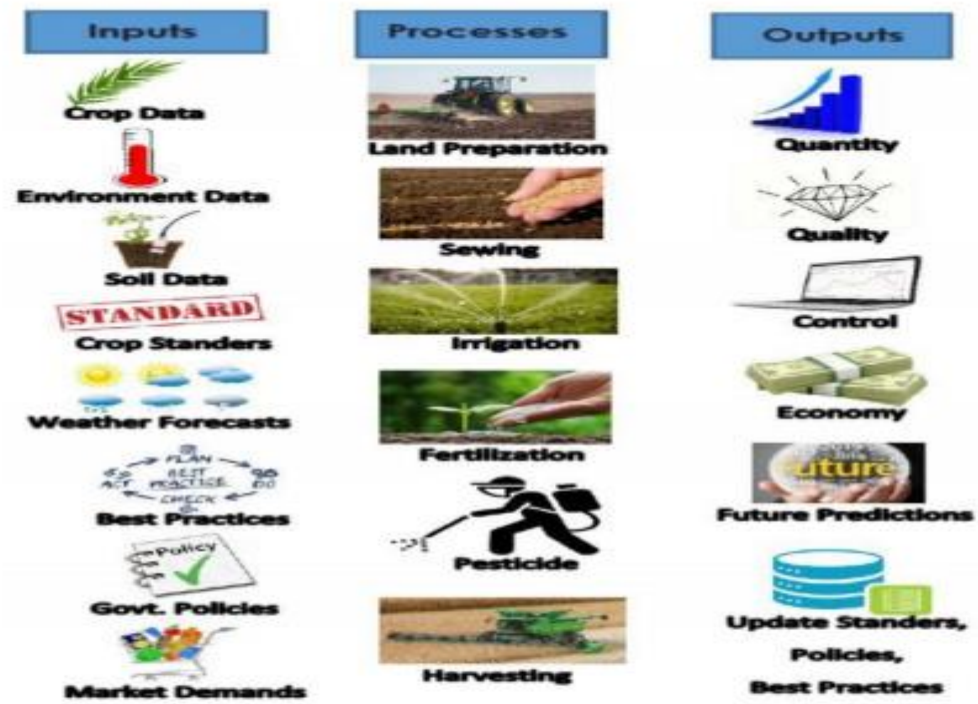
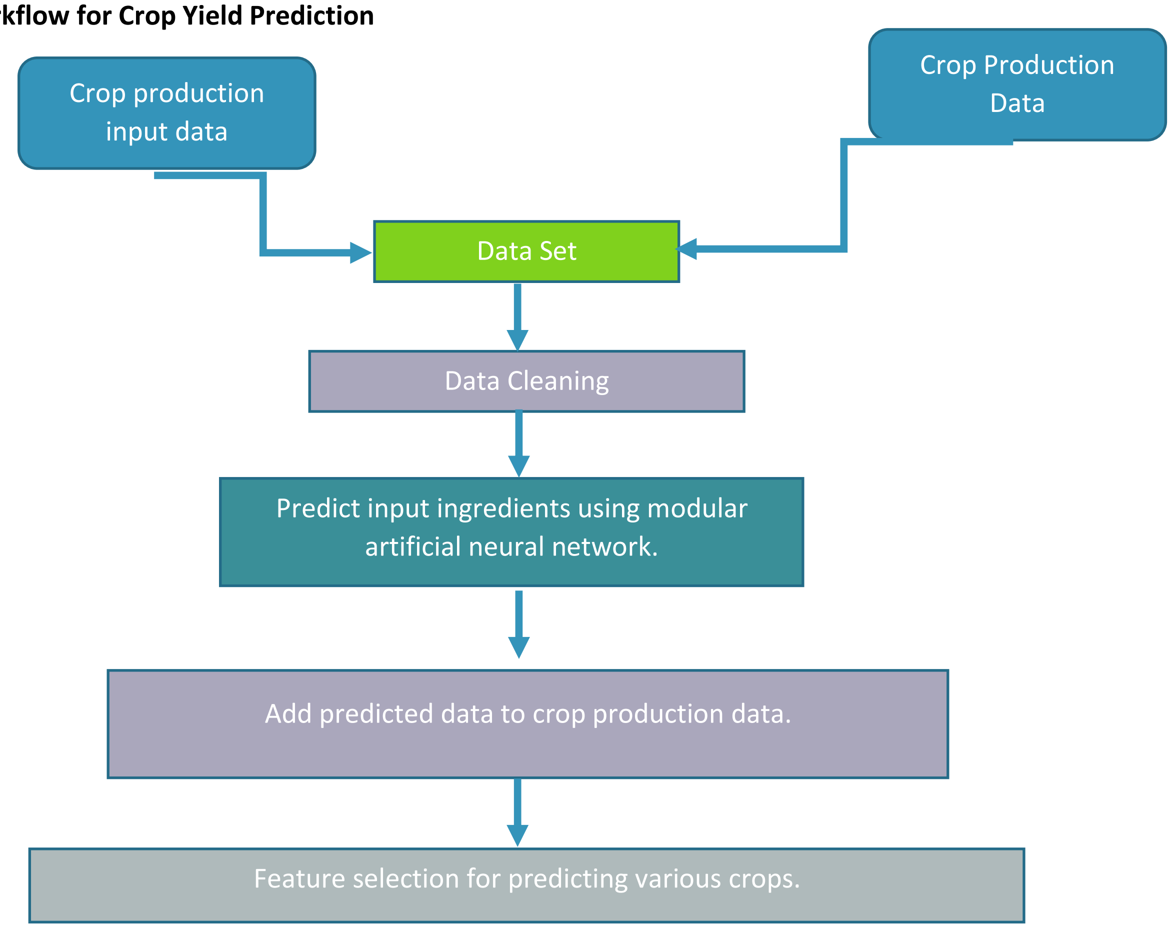


Figure 9: Some key inputs, processes involved and possible outputs of smart farming yield monitoring, forecasting and harvesting

Workflow for Crop Yield Prediction



Testing

1.1.1 Verification Stage

Software will be tested based on process used for its development. A white box testing technique will be applied that will focus on the structure and logic that will comprise of skeleton system of the software.

1.1.2 Validation Stage

The project will be tested for its functionality. A black box technique will be applied that will focus on testing the software against the program specifications.

1.1.3 Stages of testing protocol

Stage 1: Unit Testing

In this state our developers will dissect the software and scrutinize its smallest units to find any grass root level problem.

Stage 2: Integration Testing

The next stage will focus on testing how well the various modules and components are integrated within the developed software. A top-down and bottom-up approach will be applied in this stage. Various interface will also be tested for any defect in this stage.

Stage 3: Sub-system and System Testing

This stage our focus will be on validating and analyzing that the software an all its sub-system complies with the requirements as specified by HarvestPlus.

Stage 4: Testing System Engineering

This stage will identify if the project tolls integrate with the external environment, APIs, external components such as computer system and other software, APIs, Cloud infrastructure, etc. as specified by HarvestPlus.

Stage 5: User Testing

This stage, also known as ***acceptance testing stage***, wherein the end user or some representative will test the final software to see if it is complete and actually performs the functions that was originally envisaged.

Implementation & Monitoring

This stage will deploy the following process flow for easy adoption, adaptation and application app by all the stakeholders in agri value chain. The implementation strategy will follow the following roadmap:

The Strategy Implementation Process

Figure 10: Grus & Grade implementation & monitoring strategic roadmap

1.1.4 Training

The training strategy will comprise of the following strategic steps for complete adoption, application and use of the new tools.

Step 1: Training Need Assessment Program

Step 2: SWOT Analysis to understand Need Gaps.

Step 3: Develop Learning Objective Toolkits

Step 4; Designing of training material.

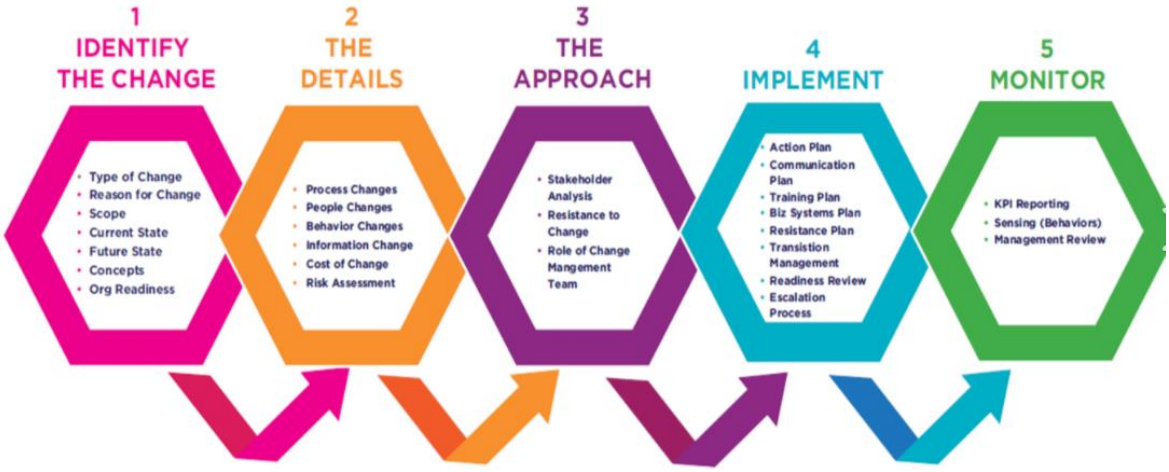
Step 5: Implement the training

Step 6: Evaluation and feedback

1.1.5 Change Management

Behavior changes for acceptance, adaptability and willingness of the farmers to adopt technology is the biggest challenge in agri domain. Grus & Grade team will ensure full convertibility based on redistribution of value creation due to adoption of technology. Communication with stakeholders to adopt technology and involvement of rural youth in the process integration is a must. Grus & Grade will deploy its team of experts and hire local resource from each village will be deployed at the end of the first phase of development and implementation for scalability, sustainability, and commercialization of the technology.

The Change Management strategies will be applied only to the extent of adoption and acceptance of this project my the operating functionaries and derivation of the values and benefits of the project by the top management for decision making process.



1.1.6 Support

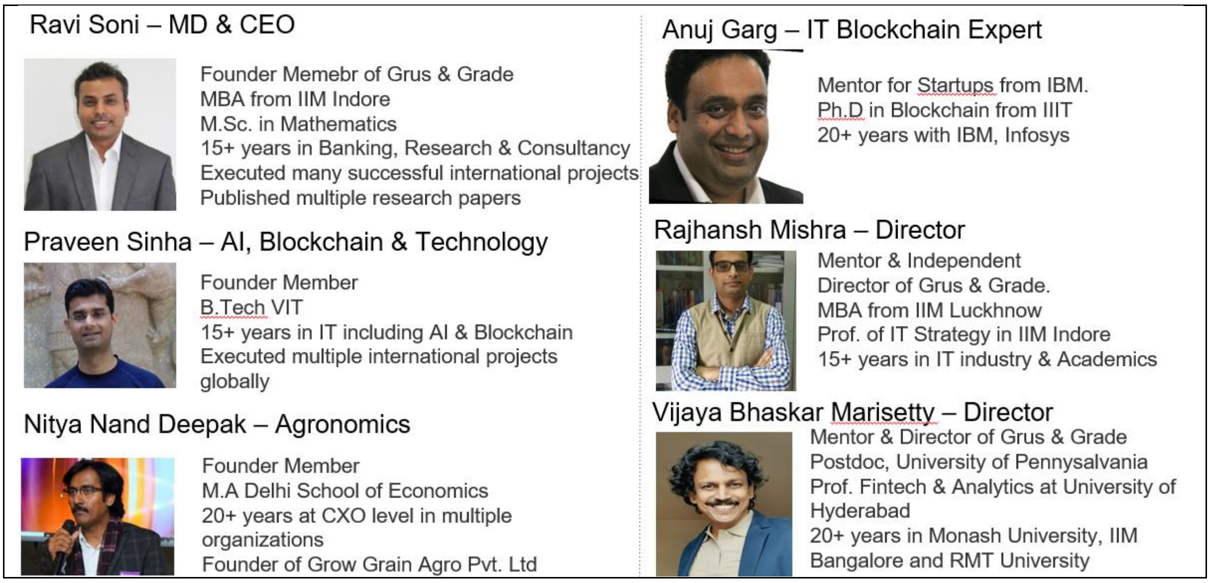
Grus & Grade offers top class post-sales support and a continuous upgradation of the services offered. We value our customer satisfaction as one of our core principles.

2. Team Structure

Three different level of teams of Grus & Grade will work simultaneously on the ideation, design, development, testing, implementation, training, monitoring and post-sale services for the project.

The price of the top management of Grus & Grade team who will work for the research, ideation and design of the project is illustrated hereunder:

Grus & Grade Team Profile



Timelines

1. POC and Prototype development: 30 days (expected to be compete by first week of May)
2. Deployment of team to Millet Growing States for app download, training, and implementation (Rajasthan, Maharashtra and Karnataka) (30 days)
3. Baseline survey for existing income of farmers, millers, seed companies, distributors, food processors, etc (to calculate the value generated without use of technology)
4. Mid line survey and training to farmers for acceptance and adoption of technology
5. End line survey of for millets (Sept-October) to calculate the incremental value due to adoption of technology
6. Deployment of team into wheat cultivating areas (Bihar, UP, Punjab) for similar process as adopted for millers

The entire project's first phase is expected to be complete by end of two crop cycle (approximately 1 year)

Based on learnings and success of the first phase of the project, the send version with multiple features will be integrated in the app.

Project Budget

The expected budget for the entire project is Rs……..