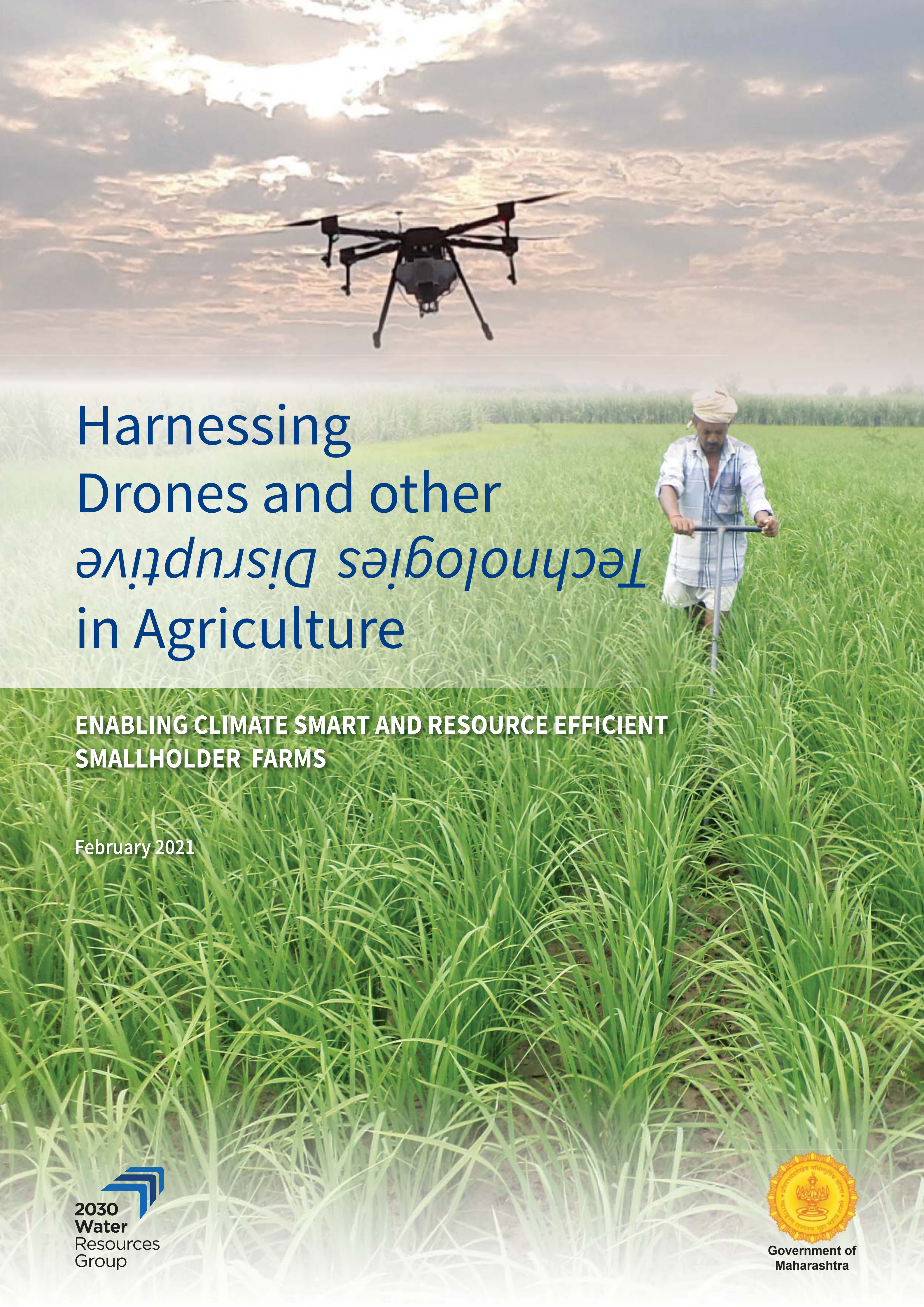

Harnessing Drones and other Disruptive Technologies in Agriculture

ENABLING CLIMATE SMART AND RESOURCE EFFICIENT SMALLHOLDER FARMS

February 2021

2030 Water Resources Group

Government of Maharashtra

About 2030 Water Resources Group

The 2030 Water Resources Group (2030 WRG) is a unique public-private-civil society partnership that helps governments to accelerate reforms that will ensure sustainable water resources management for the long-term development and economic growth of their country. It does so by helping to change the "political economy" for water reform in the country through convening a wide range of actors and providing water resources analysis in ways that are digestible for politicians and business leaders. The 2030 WRG was launched in 2008 at the World Economic Forum and has been hosted by the World Bank Group since 2012.

Acknowledgments

This White Paper is developed under the leadership of Maharashtra Water Multi-stakeholder Platform, supported by 2030 WRG, Government of Maharashtra and the contributions of a large number of people who have enriched it by offering their time, knowledge and insights during several rounds of bilateral and roundtable discussions. We wish to thank all the companies, organizations, institutions and individuals that have shared their knowledge on disruptive technologies, water resources, agri-tech, and a host of other related subjects – which we have converged to develop this White Paper.

Photo Credits

We thank VNV Advisory, Kritsnam Technologies and Drip to Market Agro Corridor (DMAC) -Ramthal, Government of Karnataka, for sharing photos for this White Paper

Digital Release - Feb 2021

Pic credit: 2030 WRG

Authors/Contributors

Rustom J Modi, Kavita Sachwani, Ajith Radhakrishnan, 2030 Water Resources Group, World Bank.

The authors are deeply grateful for the contributions of several people in the creation of this White Paper. We would like to sincerely thank Shri K P Bakshi, IAS (Retd.), Former Chairman, Maharashtra Water Resources Regulatory Authority; Shri V K Gautam, IAS, Additional Chief Secretary, Water Resources Department; Shri SVR Srinivas, IAS, Principal Secretary, Department of Housing and Former Principal Secretary Department of Information Technology; Smt Abha Shukla, IAS, Principal Secretary, Department of Information Technology; Shri Vikas Rastogi, IAS, Principal Secretary and Project Director Project on Climate Resilient Agriculture; Shri Eknath Dawale, IAS, Secretary, Department of Agriculture; Shri Prasad Kolte, Chief Operating Officer, Drones Cell, Maha IT; Dr. Sanjay Belsare, Joint Secretary, Water Resources Department; Dr. Rajendra Bharud, IAS, District Collector, Nandurbar, Government of Maharashtra; for their valuable inputs and guidance on shaping the White Paper to align it to the Maharashtra context. A special word of thanks to Shri Amber Dubey, Joint Secretary, Ministry of Civil Aviation, Government of India for his timely inputs and guidance.

We also thank Dr. S Gorantiwar, Head, Dept. of Agricultural Engineering Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri; Shri Vilas Shinde, Founder of Sahyadri Farms; Sandeep Roy Choudhury, Co-founder Director, VNV Advisory; Hemendra Mathur, Independent Agri-Tech expert and member of the 2030 WRG Maharashtra MSP Taskforce on Innovative Financing for Climate Resilience in Agri Value Chains; N Meyyappan, Leader Social Sector Practice and Huzefa Tavawalla, Head, Disruptive Technologies, Nishith Desai Associates; Sai Gole and Siddharth Dialani Co-founders of Bharat Agri; K Harsha, Founder of Kritsnam Technologies; Purushottam Kaushik, Head, Centre for Fourth Industrial Revolution, India; Sachin Kamble, AGM, P Usha Mani GM, NABARD who helped in providing incisive inputs on agronomy, technology and not only designing the contours of the pilot to match the fast moving scenario in the Agri-Tech and climate smart agriculture space but also come forward to form a consortium to launch the pilots.

We are also grateful to the Drones Federation of India (DFI), for their valuable inputs and industry connects and several other stakeholders of the Maharashtra Water MultiStakeholder Platform that we have engaged with during the course of the development of this White Paper.

We thank Shri Nagaraja Rao Harshadeep, Global Lead, Disruptive Technologies, World Bank for sharing his experience and inputs on how disruptive agriculture technologies can support climate smart agriculture towards building resilient, sustainable and inclusive farming ecosystems leading to farmer prosperity.

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Pic Credit: VNV Advisory

Executive Summary

Sector Context

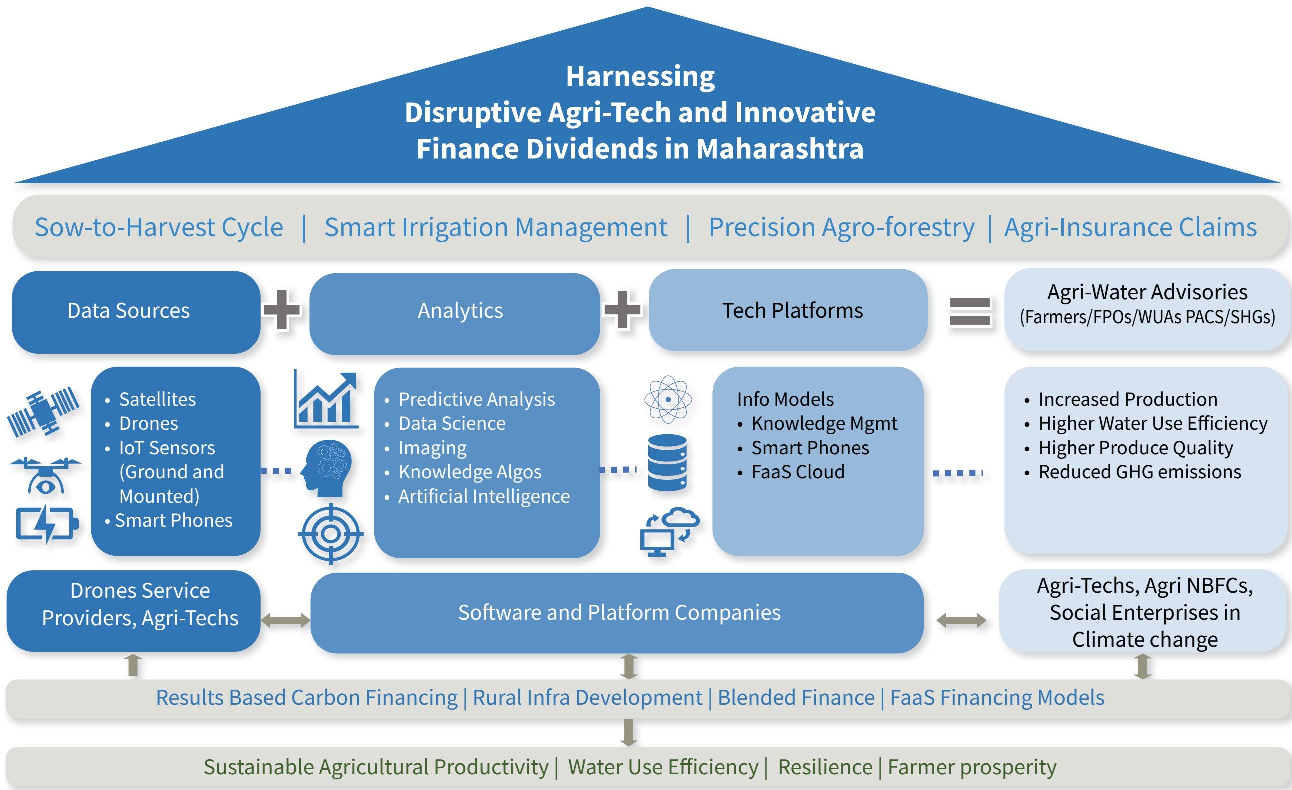
Climate resilient agriculture and water conservation are strategic imperatives to achieve the goal of sustainable agricultural growth given the global climate crisis and its impact on water, soil and the environment. In order to achieve this at scale, it is important to harness appropriate technologies and empower smallholder farmers by increasing farm yields and productivity, reducing water loss, and improving and preserving soil quality.

The current thrust in agronomy is centred around data and its use in real-time actions as possible, and the predictive risk mitigation it brings to bear for farmers. Sensors, which can be mounted on the ground or on agricultural equipment, are a means to collect data. The goal of precision agriculture is to increase farm yields by using fewer resources, together with a lighter environmental footprint.

Drones and satellite-based mapping services have gained high levels of acceptability, and now intersect with ground-based, sensor data, providing greater accuracy and insights into agricultural conditions and practices. The pace and scale of growth of digital and software applications for Agri-Tech is significant both globally and in India.

Objective and Scope of the Initiative

The White Paper addresses the fundamental question of how improved farm-level decision making, harnessing the power of a data platform through integrating drones, satellites, and ground-based IoT sensors, can significantly improve decisions, increase crop yields, improve water use efficiency and enhance incomes of smallholder farmers.



The White Paper proposes successful implementation supported by stakeholder ownership, robust go-to-market strategies, carefully prioritized pilots in different agro-climatic zones in Maharashtra, leading to a production roll out as critical to the penetration of disruptive technologies in agriculture.

While keeping technology at the core of the White Paper and pilot(s), the following areas are also being concurrently addressed through a multi-stakeholder, consultative approach:

- **Enabling Policies**: inputs to policy making for transforming Maharashtra into a disruptive agricultural technology- knowledge hub by leveraging on existing government policy initiatives and improving technology penetration for the benefit of its smallholder farmers
- **Impactful Business models**: integrating service delivery approaches at various points in the agricultural value chains to promote Farming-as-a-Service (FaaS) in Maharashtra
- **Cost benefits**: unravelling the benefits and co-benefits of technology solutions and key costs of technology-service access and delivery in smallholder farms for improving adoption
- **Large Scale Pilot Program:** bringing together innovation consortia of stakeholders from supply side to demand side; including the government, industries, investment community, civil society, academia and farmer user groups to foster the deployment of disruptive agricultural technology solutions in Maharashtra through value chain integration, demonstration of multiple applications at scale and in a usage context, and as close as possible to operational condition
- **Key risks and mitigation strategies**: identifying and evaluating strategies to mitigate such risks as execution of the large-scale pilot initiatives progress
- **Innovative Financing:** Identification of stakeholders and structures for innovative financing models for the pilot(s) based on multiple outcomes, as well as production rollout
- **Strengthening Collaboration and Public-Private Partnerships**: defining and establishing a multi-stakeholder committee, bringing together users, technology service providers and intermediaries to demonstrate feasibility and define a roadmap for further implementation

The desired outcome from this initiative is to provide reliable, real-time farm advisory services for smallholders that increase farm incomes and resilience through sustainable agricultural practices. A multi-layer encapsulation of the initiative is shown below.

Methodology

The White Paper was initiated by the Maharashtra Water Multi-stakeholder Platform supported by the 2030 WRG which facilitated extensive consultations with a diverse range of stakeholders. These included various departments within the Government of Maharashtra, the private sector including technology providers, agri-techs, financial institutions, and academia, who have provided valuable inputs to shape the White paper and the proposed pilots. Critical Success Factors have been identified as also key risks and strategies for their mitigation. A framework to capture and evaluate cost-benefits is being developed, and will be refined during the course of pilot execution.

Use Cases

The following four use cases identified for implementation for the large scale pilots are the following:

- **Sow-Grow-Harvest crop cycle** with farmer advisory services to improve yields, reduce fertilizer and reduce the use of pesticides and optimise the use of water resources.
- **Smart Irrigation Management** through optimising water consumption through targeted irrigation/ water release and measuring the stock and flow of water and water infrastructure
- **Precision Agro-Forestry** through harmonizing land use and it's conservation, improvement in soil and water conservation initiatives, and the increase in biomass through intensive afforestation.

- **Agri-Insurance Claims Management –** Drones increase penetration in the smallholder risk insurance market using pooled approaches to risk management. Opportunities that can be explored include the use of drone flight damage inspection and pay-out or premium calculations, and in the event of a claim to evaluate the damage for indemnity.

The use cases, in the illustration, form the solution set for Disruptive Agricultural Technology (DAT) Integration of data from satellite and drone imagery and field based IOT sensors will provide a comprehensive dataset for predictive analytics and improved decision making and farmer advisory. The application of Artificial Intelligence with Machine Learning (AI-ML) only adds to the scalability and ability to take data based decisions. The overarching aim of implementing appropriate technology is to achieve scale, defray expenditure across multiple stakeholders through execution models such as Farming as a Service (FaaS), and to ensure that technology helps bring about positive environmental change through sustainable farming.

FaaS Model

'**As-as-Service**' models have emerged over the last two decades. These models allow access to usage of an asset on *Opex* basis rather than on a *Capex* basis. The asset in consideration here is information that is required by the farmer to improve crop yield, effective water management, and maximizing the impact of chemical fertilizer and pesticides. The farmers only pay for services specifically subscribed by them, and should be able to measure commensurate improvement in crop yield. Financing models to further make affordability and farmer participation could include performance based subscription models, wherein farmers pay on a revenue sharing model only if there is an actual improvement in yield.

Pic Credit: 2030 WRG

Pilots Program

The pilots envisage a syncretic approach of blending three technologies viz., Drones or Unmanned Aerial Vehicles (UAVs) and Satellite based data; Ground-based IoT sensors; and an integrated Analytics Platform and Decision Support System that incorporate Artificial Intelligence-Machine Learning capabilities.

The drivers for selection of pilot locations include agro climatic conditions, crop mix, water characteristics (rainfed and/or irrigation command areas, water table levels). Additionally, the availability of localised data, the ability of local partners and farmers to adopt disruptive technologies together with stakeholder financing, base level connectivity and infrastructure have played a role in pilot selection. Pilot locations selected meeting the above criteria are: (i) **Hingoli,** Aurangabad district, (ii) **Nandurbar**, Nandurbar District and (iii) **Nashik**, Nashik district.

Discussions with Agri-Tech start-ups, drones and technology service providers and several other stakeholders are being pursued for innovative Agri-Tech solutions that fit the use cases in the three pilot sites. Stakeholders include UAV providers and Satellite Data service providers, Agri-Tech start-ups, field support, technology platform and software companies, and academic and specialist institutions. 2030 WRG is supporting the MSP along with the pilot stakeholders to draw up a roadmap for the initiative to effectively orchestrate and implement the pilots. Active involvement of Indian Agri-Tech start-ups and the innovation incubators of state agricultural universities and international organisations is being sought as knowledge partners. Financial viability is being envisaged through funding strategies using Blended finance and other innovative financing mechanisms executed by Agri-NBFCs, social enterprises and FPOs. A results-based carbon financing mechanism is also being integrated in one of the pilots. Dissemination of agri-water advisories to the farming community will help realise the envisaged outcomes as well as contribute to the achievement of SDG 5, SDG 6, SDG 12, SDG 13, SDG 15, SDG 17 among others.

Way forward

The Ministry of Civil Aviation (MoCA), Government of India, has initiated a comprehensive set of policies and strategy to ensure that drone technology and applications are implemented across India. The aspiration is for India to assume the leadership role in UAV technology solutions and their adoption.

The initiative has received an in-principle support from the MoCA and the pilots being drawn up are being aligned to comply with current (and future) regulatory framework laid out by the DGCA.

In conclusion, the pilots will form an important exercise for all stakeholders to understand both the possibilities and learnings that the implementation of disruptive technologies could have on Maharashtra's initiatives on technology enabled agriculture. Data collected through the pilot will enable understanding the likely acceptability and rate of adoption by the farming community; and allow for the identification of both costs and benefits that could accrue over the longer term. Policy makers and financing institutions will have more granular information to target interventions that support such technologies and benefit farmers.

The White Paper and the pilots prioritized for roll-out, will deepen our understanding of last-mile technology adoption barriers for *Disruptive Agricultural Technologies.* It will also strengthen and expand the fit-for-purpose business cases for smallholder farmers leveraging on partnerships between government, private sector and the civil society. The White Paper, as the Water-Multi Stakeholder Platform for Maharashtra is convinced, will bolster Maharashtra's thought leadership in Disruptive Agricultural Technologies.

I. Overview

Introduction

The 2030 Water Resources Group (2030 WRG) is a global public-private-civil society platform conceived in the World Economic Forum in 2008 through the collaboration of a group of governments, multinational companies, multilateral agencies and international non-government organizations. In 2012, the role of administrating the platform moved to IFC's Advisory Solutions Group and it is currently being hosted within the World Bank Group since 2012.

The primary aim of 2030 WRG is to develop partnerships at a national / sub national level that can assist state governments to accelerate actions to increase water resources sustainability and water efficiency across the economy. This is based on the recognition that demands for water are increasing dramatically with economic and population growth, and that, assuming a continuation of current trends, the world is predicted to face a 40% gap between available renewable water supply and water demand by the year 2030. It is also based on the recognition that the public and private sectors have a common interest in strengthening water resource management and can achieve far more by acting in partnership than alone.

2030 WRG is active in 11 countries in Asia, Sub-Saharan Africa and India – where it is present in Karnataka, Maharashtra, Uttar Pradesh and Madhya Pradesh. In May 2017, 2030 WRG in partnership with the Government of Maharashtra, private sector companies, and civil society organizations, formalized a Water Multi-Stakeholder Platform (MSP), chaired by the Chief Secretary, Government of Maharashtra. The Maharashtra Water MSP has the following workstreams:

- Water and Livelihood Security in Rain-fed Agricultural Areas
- Command Area Water Productivity
- Wastewater Reuse and Management
- Industrial Water Use Efficiency and Security

In addition to the three workstreams mentioned above, 2030 WRG is spearheading cross-cutting initiatives in (i) Gender- Water – Agriculture, (ii) Water Accounting, (iii) Alternative Financing in the Water sector (iv) and Disruptive Technologies for the Water sector. In all the above, 2030 WRG team brings innovations to support its primary mission of promoting water use efficiency and water productivity to transform value chains, build resilience and water security.

Sector Context

Global population will touch 8.5 Bn. in 2030 and 9.8 Bn. by 2050, with India's population estimated at 1.5 Bn. in 2030 and 1.65 Bn. in 2050[1]. Climate change is increasingly impacting our world, and a conservative estimate of global warming is around a 1.5 degree C increase in temperatures by 2030 due to an increase in green-house gas emissions and environmental degradation.

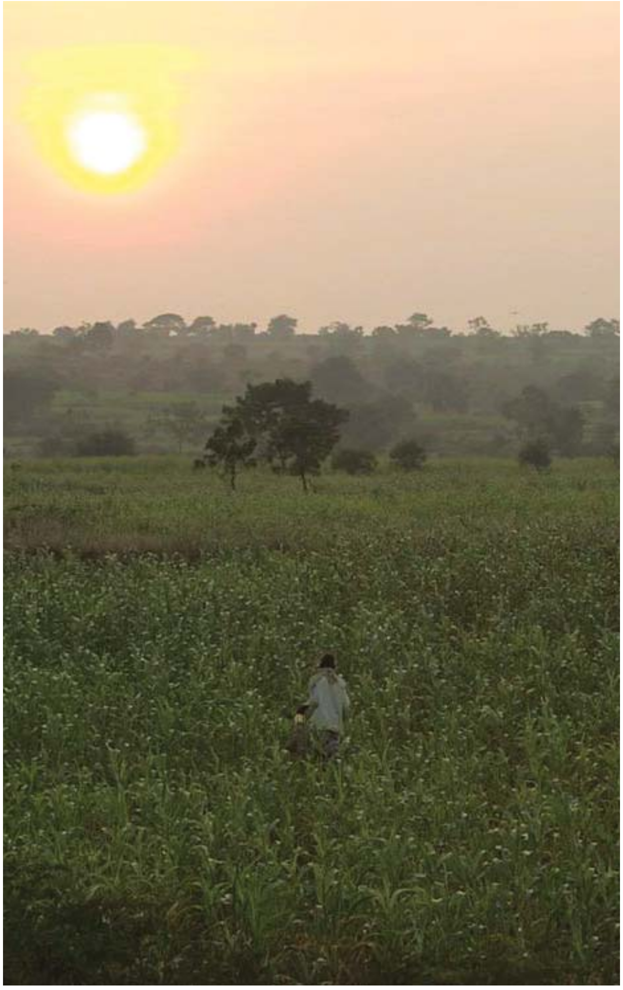
Key challenges for agriculture and water resources in India revolve around greater urbanisation and industrialisation, as they compete with agriculture for both land and labour; and impact both climate and environment. Agriculture in India employs about 70% of the population, consumes around 75% of the country's water resources, and contributes around 15% to national GDP. Technology driven interventions are required to achieve greater production and productivity..

The successful leveraging of technology and its application in the wider sense will have significant impact on achieving global SDG goals. Agri-Tech and Precision farming encompass a set of technologies which continue to evolve, and include Sensors (IoT), UAVs, Robotics, and of course software platforms and telecom infrastructure. Artificial Intelligence (AI) could potentially revolutionise Agri-Tech based decision

[1] UN Dept. of Economic & Social Affairs

making. These enablers are taking centre-stage in the push to achieve greater productivity and efficiency in the agronomic and water resource universe. Agri-Tech also encompasses new paradigms such as Aquaponics, Hydroponics and Vertical farming, together with livestock and aquatic management. There is global awareness to incorporate Agri-Tech into sustainable food production, and nations are beginning to prioritise the Agri-Tech industry, which is forecasted to grow at a global CAGR of 9.8%, from USD 13.8 Bn. in 2020 to USD 22 Bn. by 2025[2].

Innovation continues to create new business models such as Farm-as-a- Service (FaaS), where farmers and farmer co-operatives do not own much of the technology or equipment, but receive actionable information and insights these as a service, thus not incurring either capital investment nor direct operating and maintenance costs. The model also allows for wider adoption as expertise is not a barrier to adoption.



Pic Credit: 2030 WRG

Maharashtra Agri-Water Context

Maharashtra is the second largest state (30.8 million ha) with the third largest population (112.4 million)[3] in India; and the most industrialised in India, contributing to around 14.4% of the national GDP, with a growth rate of around 7% per annum. Agriculture contributes around 10% of the GDP, but employs around 50% of the state's population and consumes more than 80% of the state's freshwater (surface and groundwater). Approximately 45% of the population live in cities and towns[4] while over 50% of overall population is directly or indirectly dependent on agriculture for their livelihood.

Rainfall scarcity and frequent droughts, unseasonal rains and floods are increasingly impacting the region. The distribution and availability of water in the state is highly uneven, both spatially and temporally; most of the rainfall occurs in just 40 to 100 days with extreme variations ranging from 400 mm to 6000 mm. Almost 55% of the renewable surface water and groundwater resources are located in only one basin. The *West Flowing River Basin* maintains 25% of the State's population and only 10% of the total cultivable land[5]. The remaining four basins together constitute 75% of the State's population, and nearly 90% of cultivable area draws from the balance 45% of water resources. The challenges and complexities on the state water resources management have been rising owing to declining freshwater resources and increasing contestation amongst different categories of users. Extreme events, such as droughts and floods as well as poor health of river bodies have posed additional challenges. Difficulty in providing reliable access to safe drinking water, sluggish technological innovations, inadequate financial outlays, and limited knowledge support to policy measures also contribute to the complexities in the sector.

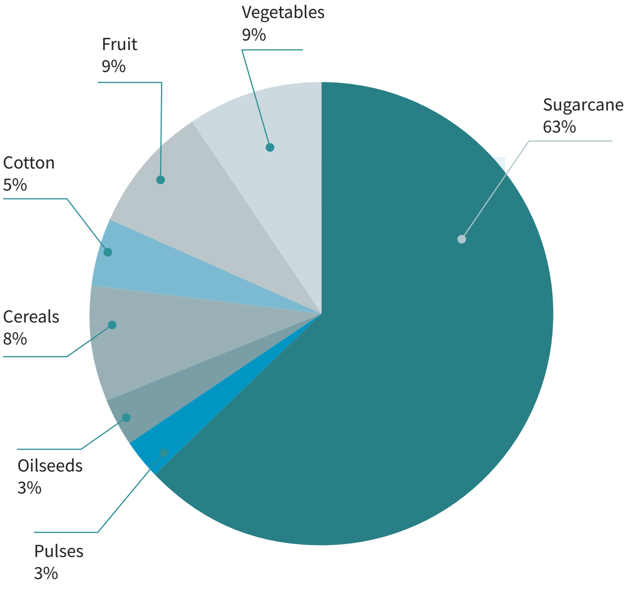
The average growth of agriculture in the state has been 3.5% in the period 2005-2015. Severe drought over the past few years has adversely impacted the sector. Farm

[2] Markets & Markets
[3] India Census 2011
[4] Economic Survey of Maharashtra 2018-19, Govt. of Maharashtra
[5] Integrated State Water Plan for West Flowing Rivers, 2018

holdings on average are 1.44 Ha., with only 20% of arable land irrigated. Both the Kharif and Rabi seasons are farmed.

The key crops and their share of produce in the state in 2018 are as follows:

MAHARASHTRA: CROP PRODUCTION



	Production '000MT
Sugarcane	83138
Cereals	10944
Cotton	6094
Oilseeds	4208
Pulses	3684
Vegetables	12307
Fruit	11729

Data Source: Economic Survey of Maharashtra, 2018-19

Crop production is dominated by sugarcane (63%), followed by vegetables (9%, onion and tomato), fruit (9%, consisting of mango, oranges, grapes, pomegranate), cereals (8%, mostly rice, *jowar*, maize) and pulses (3%, *gram*, pigeon pea or *tur*). For oilseeds, soybean is the key produce. Cash crops continue to dominate with diversification into horticulture.

Overall crop productivity continues to increase, however yields remain stagnant, underpinning the need for increased climate resistant farm policies and practices. Pilot project areas[6] demonstrate forecasted temperature increases by around 1.5C by 2030, and though the monsoon rainfall is forecasted to increase, this will occur over a shorter time period. As most of the areas are rainfed, the impact of monsoon variances on yields has a direct correlation.

The Government of Maharashtra is implementing solutions - both tactical and strategic, around farming systems, farm to market value chains and the strengthening of rural institutions, to alleviate the impact of climatic events. Technology intervention, agronomic practices and investments are all aimed at achieving climate resilience in agriculture, increasing the efficiency of water use, and increase crop productivity.

The World Bank-supported, irrigation sector improvement through the Maharashtra Water Sector Improvement Project (MWSIP, concluded in 2013) led to first generation of institutional reforms and capacity building, including setting up of MWRRA (Maharashtra Water Resources Regulatory Authority). The state continued on this path and adopted more reforms in the irrigation sector, which covers nearly 20% of agriculture area in the state. To address climate-induced vulnerability and safeguard agricultural growth, the Government of Maharashtra has launched several initiatives through World Bank funded projects such as the Project on Climate Resilient Agriculture (PoCRA), State of Maharashtra Agribusiness and Rural Transformation (SMART) and the Atal Bhujal Yojana (ABY).

6 Pilot Project Areas are locations which are identified for launching pilots defined in the section on Pilots in this White Paper

Indicative Agri-water challenges and their impacts are highlighted in the table below.

Land status	Impact
Fragmented holdings	H
Water runoff due to terrain	M
Lack of forest cover	M

Soil quality & health	Impact
Intensive farming leading to denudation	H
Erosion	H
Loss of nutrients	H

Climate conditions	Impact
Monsoon variations in intensity, timing, duration	H
Severe temperature fluctuations	H
Weather info /warning	H

Agri. Inputs	Impact
Seeds quality, availability, cost	M
Fertilizer	M
Power	H
Capital	H

Water resources	Impact
Monsoon variations in intensity, timing, duration	H
Bunding & Contouring of land	M
Maintenance of Ponds, Tanks and Wells – water resilience	H
Irrigation & sustainability	H

Information & Technology	Impact
Connectivity & access	H
Data sets, both owned and accessed	M
Total cost of ownership of IT assets	M

H high, M medium, L low

Pic Credit: 2030 WRG

II. Objective, Scope and Methodology

In response to COVID-19, in April 2020, the 2030 WRG together with the Centre for Fourth Industrial Revolution (C4IR), United Nations-Technology Innovations Lab (UNTIL) and Nishith Desai Associates (NDA), reached out to the Government of Maharashtra to explore the potential of using drones to deliver relief. This in turn lead to the genesis of this White Paper to explore the use of drones and satellite imagery and other Disruptive Agriculture Technologies, to transform agri-value chains, building long term economic resilience and food security.

Objective

The White Paper has been developed as a response to the above discussions with an immediate objective to define the use cases, evaluate the cost-benefits and architect a 'go-to-market' solution to accelerate the adoption of relevant technologies on a pilot basis in Maharashtra, to deliver value to the Agri-water sector, increase farmer yields, and lower environmental impact, while preserving livelihoods and eventually resulting in farmer prosperity.

The technologies in focus are for the use of (i) satellites and drones, (ii) technology platforms and (iii) analytics to store, analyse and make predictive decisions for a offering advisory services to farmers.

Scope

The Scope of the White paper is as follows:

- Evaluate the feasibility of and interweave the use of UAV /Drones and satellites to capture relevant data, with the complimentary technologies of IoT and data platforms to store, analyse and make predictive decisions for offering advisory services to farmers
- Define and prioritise key societal / economic challenges that the technologies will impact and outline the specific use cases for which such technologies can be used
- Execute a technology scan to select appropriate technologies and partners
- Carry out a high-level Cost-Benefit Analysis, analyse and define key project risks, and mitigation strategies (Will take shape during the course of the pilot)
- Define and agree Pilot project(s) to demonstrate feasibility with relevant partners and stakeholders, and recommend Phase 2 implementation that is a "production" state wide rollout

Use case and potential pilots have been evaluated looking to cost and timeframe for implementation, with a focus on operationalisation at the ground level in the Indian context. The Use cases for the Pilot are described in Section VI of this paper.

Methodology

The following methodology has been followed for developing the White Paper.

Adapting Systems Dynamics Theory

The contextual understanding of agriculture and water touches upon the need for optimisation of scarce resources. Elements from the Systems Dynamics theory have been used to analyse and re-inforce hypotheses, that as a "societal systems approach" to evaluating complex, high impact problems, is appropriate. Causal relationships have been defined to better understand and analyse linkages within the wider agrarian societal system.

Risk analysis

The approach to risk has been to group the risks into various categories – Project (macro risks), Technology, Financial, Skills & Implementation. Potential mitigation strategies have been identified. The objective has been to follow a logical framework for analysis, and not produce quantitative output or formal heat-maps.

Critical Success Factors

The approach to Critical Success Factor (CSF) analysis is to identify the key objectives, define the CSFs' for the objective together with the Key Performance Indicator that measures the meeting of the objective. CSFs for Operational, Technical, Financial and Human Resource skills have been developed and refined as the pilot progresses.

CSF includes (by Category) Output measures – Yield, Productivity measures – (output) of land, labour, crop production, (inputs) of fertilizer, capital; and Efficiency measures – wastage reduction – input and output, time and cost reduction.

Cost-Benefits

The approach to cost-benefits has been to define a framework to outline the parameters of the analysis, calculate costs and benefits so they can be categorized by type, and intent (across the life of the project). Compare & analyse cost and benefits using aggregate information. Cost-Benefit analysis will commence with pilot implementation. The caveat is that benefits will be realised over an extended period of time, and time-series data will have to be collected.

The primary categories that costs and benefits fall into are **direct/indirect**, **tangible/intangible**, & **real**:

- **Direct costs** are often associated with production of a cost object (product, service, customer, project, or activity). **Indirect costs** are usually fixed in nature, and may come from overhead of a department or cost center
- **Tangible costs** are easy to measure and quantify, and are usually related to an identifiable source or asset, like payroll, rent, and purchasing tools. **Intangible cost**s are difficult to identify and measure, like shifts in customer satisfaction, and productivity levels

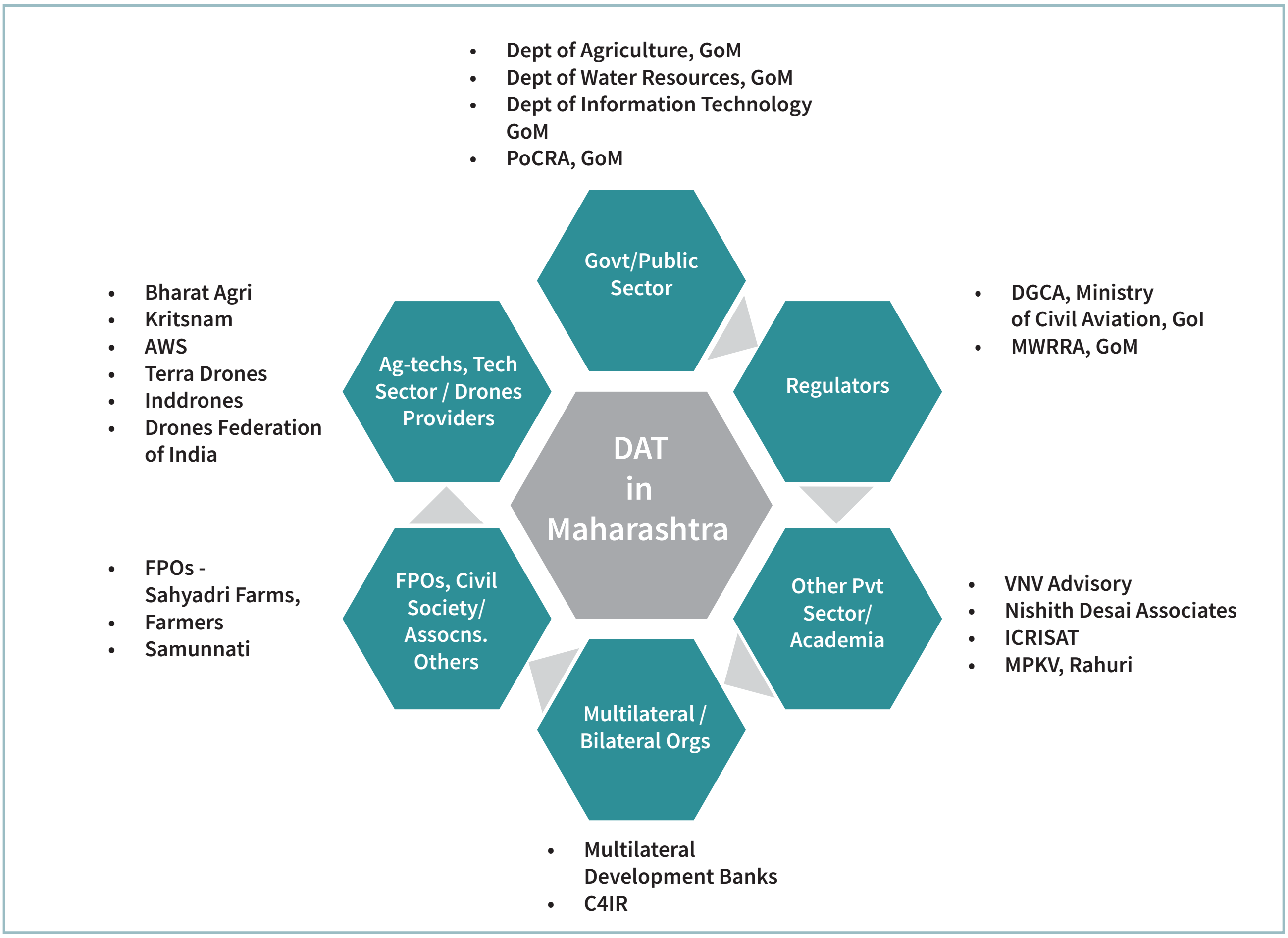
Promoting development of alternative, market-led diversification and demand-side management of water and nutrients, along with further incremental regulatory reforms for technology adoption will establish the critical mass for a competitive environment in agriculture.

Pic Credit: VNV Advisory

Key stakeholders

Extensive consultation meetings have been held with key stakeholders from the Government of Maharashtra, the private sector, Farmers / Farmer Producer Organisations and academia, to understand the issues and status at a local level, and define Key Performance Indicators (KPIs) at a macro project level.

We have been engaging with several stakeholders and partners who have come forward to be a part of this initiative.



III. Contextual Understanding of Agriculture and Water

Overview

Clean water and sanitation are central to global development and well-being, and the UN's Sustainable Development Goals (SDG) address this through SDG6 – Clean Water and Sanitation. Water is vital for daily survival, agriculture and industry. However more than a billion people live in regions that have scarce or scanty water resources. Continued habitat destruction and climate change only exacerbate the threat.

Water resources in India

For India and much of the developing world water stress is a result of the following:

- Climate change
- Socio-economic movement – both urbanisation and an increase in incomes with the resultant impact on diet and agriculture
- Habitat destruction and groundwater depletion

India accounts for around 18% of the world's population and 4% of it's water resources and is ranked 13th in terms of being the most high-risk water stressed countries on the planet. The country has to contend with competing demands for it's water resources, from agriculture, industry and urban development. On the supply side it faces increased stress from climate change and the resultant changes in the monsoon pattern, and the retreat of glaciers in the Himalayan ecosystem. India's river systems are either rain-fed (the western, southern and central systems), or glacier-fed (typically the northern riverine system).

At the current rate of depletion groundwater and aquifer levels will fall below 50% of demand by 2030; and 54% of India will face high to very high water stress Over 50% of the wells across India face decreasing levels. No limits are imposed on the level of groundwater extracted, and there is rampant use of bore wells, leading to water table recharge becoming unsustainable.

Agriculture in India

As part of India's commitment to the United Nations Framework Convention on Climate Change international treaty to reduce the emissions intensity of its GDP by upto 35% by the year 2030 form a base of 2005. Sustainable climate resilient agricultural practices and polices form a cornerstone of the strategy to achieve this. Agriculture is a vital engine of economic sustenance in India, employing around 65% of the population, and accounting for 18% of GDP. Agriculture also contributes to green-house gas emissions, which though through climate-resilient farming could see a reduction. India is the world's third largest GHG emitter in 2018[7] (China is first followed by the USA).

Promoting development of alternative, market-led diversification and demand-side management of water and nutrients, along with further incremental regulatory reforms for technology adoption will establish the critical mass for a competitive environment in agriculture.

[7] UCUSA, 2020, Accessed online at: http://ucusa.org on 12th Feb 2021; The 20 countries that emitted the most carbon dioxide in 2018

Key challenges:

Climate change and biodiversity loss or erosion – impacting the monsoon which is becoming more erratic with variations. Spatial and temporal variations and intensities, coupled with recurring in intensity, heat waves, floods and droughts

Fragmented and small land holdings leading to farms becoming uneconomic, and factors of production and technology enabled agriculture becoming difficult to implement

Scarcity of land and the need to intensively farm through multi-cropping leading to land degradation

Volatile global commodity and agricultural prices

Access to pre and post harvest finance for smallholder farmers

Solutions for will have to focus on increased productivity through the entire value chain from farm management and production, through to marketing and consumption. At the level of the farm this includes productivity and efficiency increases for all inputs – land, labour and capital, and all outputs. Going forward, resilience, accurate data collection, analysis and measurement will play a vital role in Indian agriculture.

IV. Landscape for Disruptive Agriculture Technologies

Overview

The proposed pilots will evaluate the use will evaluate the of using UAV and satellite based imaging and sensor technology, including ground based micro climate sensors, to capture relevant data. Satellite based remote sensing data in conjunction with drone based imagery will be uploaded to a data platform for further analysis, and the delivery of farm specific advisory to improve yields and economic returns, while minimising the use of chemical fertilizer and pesticides, as well as using water resources effectively. The scope therefore is to:

- Evaluate the potential use of drones in conjunction with satellite data, IoT and the supporting data and analytics to execute the use cases that constitute the pilot study
- Execute drone based data capture to survey, evaluate and capture data for agriculture and irrigation. Drone mounted aerial cameras and /or sensors are the key technologies used. Additionally, various specialised equipment for spraying etc. may be mounted depending on the type and capacity of the drone. Analysis of satellite remote sensing imageries provide opportunities for historical trend analysis of variables considered. The pilot(s) will seek to ascertain an optimal mix of data collection from both sources to help understand the optimal data collection mix.
- Evaluate and define how this field level data matches or differs from data sourced from satellite images
- Implement IoT devices where contextually appropriate
- Big data and analytics is used to measure past and current performance, and predict future trends of crop yields.. With real-time data actionable insights and course correction is key
- Data assets revolve around govt and private sources, as well as locally sourced and available data at pilot locations. For the pilot, the data paradigm in essence, covers data platforms, its collection, storage and analysis

Use Case Implementation

Use case identification, execution and analysis will broadly follow the process laid down.

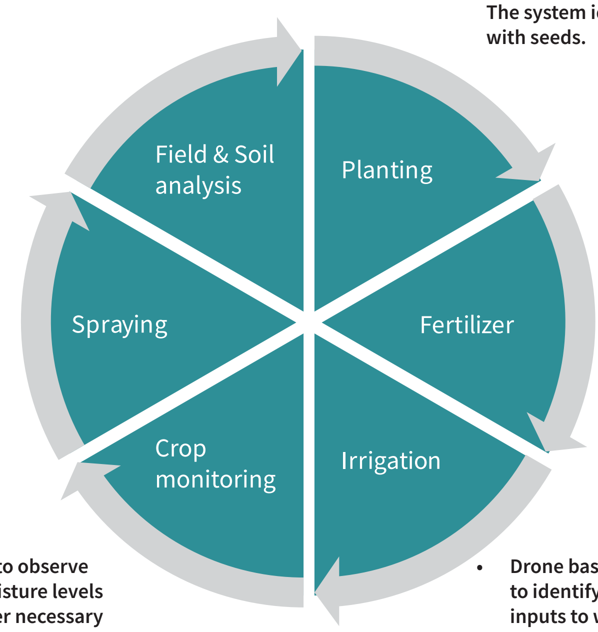
- Definition of Use Case: it is imperative that all stakeholders understand and agree to the goals and Critical Success Factors (CSF) for each use case. This is key to the success of the pilot and for measuring the likelihood of "production" success
- Product components in the solution: this stage in the process identifies all the components that will go into the solution – hardware/equipment; solution sets; teams etc.
- Cost-Benefit analysis: evaluate the costs and understand both the direct and imputed benefits for a production rollout. A caveat is that the pilot in itself will not be of a long enough duration to measure benefits.
- Deployment SWOT and Risks: evaluate the strengths, weaknesses, opportunities and threats from pilot execution and plan an execution strategy for scaled "production" rollout of the initiative across Maharashtra. Identify the key risks and mitigation strategy for such a rollout.

Use case potential

- Soil Analysis prior to sowing to help determine suitability, seed type & planting patterns

- Drone based planting system especially in remote/ rough terrain. The system ideally shoots pods with seeds.

- Precision spraying of herbicide/ pesticides over a large area



- Inputs to crop health for targeted fertilizer applications

- Aerial imaging facility to observe the crop nutrients, moisture levels and monitoring of other necessary parameters
- Monitoring growth of crop
- Precise sprinkling water on crops, saving both time and wastage

- Drone based sensors & cameras help to identify water stressed areas & give inputs to water requirements.
- Monitoring adequate soil moisture levels for irrigation scheduling
- Monitoring stock and flow of water and irrigation infrastructure

Use case identification, execution and analysis

Definition of Use Case(s)	Product components in solution	Cost-Benefit Analysis	Deployment SWOT & Risks
• Define use case • Get buy-in from stakeholders • Synthesise • Define goals, end-game & CSF for use case pilot	Identify & finalise all products & components for the solution	• Evaluate the costs-benefits for the proposed use case • Evaluate on the ground how the solution will scale	• SWOT for scaled deployment of solution • Key risks for the solution at scale

Key considerations in implementation

- Cost of operations: with government and FPO support cost should not be a limiting factor to implement drone based solutions. It is assumed that the implementation model followed will be service based, pay-as-you-go, thus minimising both capital and fixed cost components. A robust cost-benefit assessment model for the pilot is being built.

- Acceptability and adoption: acceptability and adoption of new technology will be key. Demonstration of the benefits that can accrue to the farmer's entire livelihood, together with affordable costs will increase adoption.

- Regulatory approvals: Policy changes continue to be a pre-cursor for the wider adoption of drones. In essence these revolve around line of sight regulations; flight paths and permissions; licensing for the manufacture, operation, and piloting of drones; categories of drones allowed.

- Special purpose equipment: drones will need special-purpose cameras and sensors.

- Flight management, software & customisation: drones require navigation and flight management software, together with mapping, data and image processing software.

- Data collection platforms: both for the raw images as well as their upload to the cloud, analysis, and visualization processes need expertise. In-depth knowledge of plant physiology to instruct the software algorithms to recognize certain patterns indicating plant and soil conditions are required.

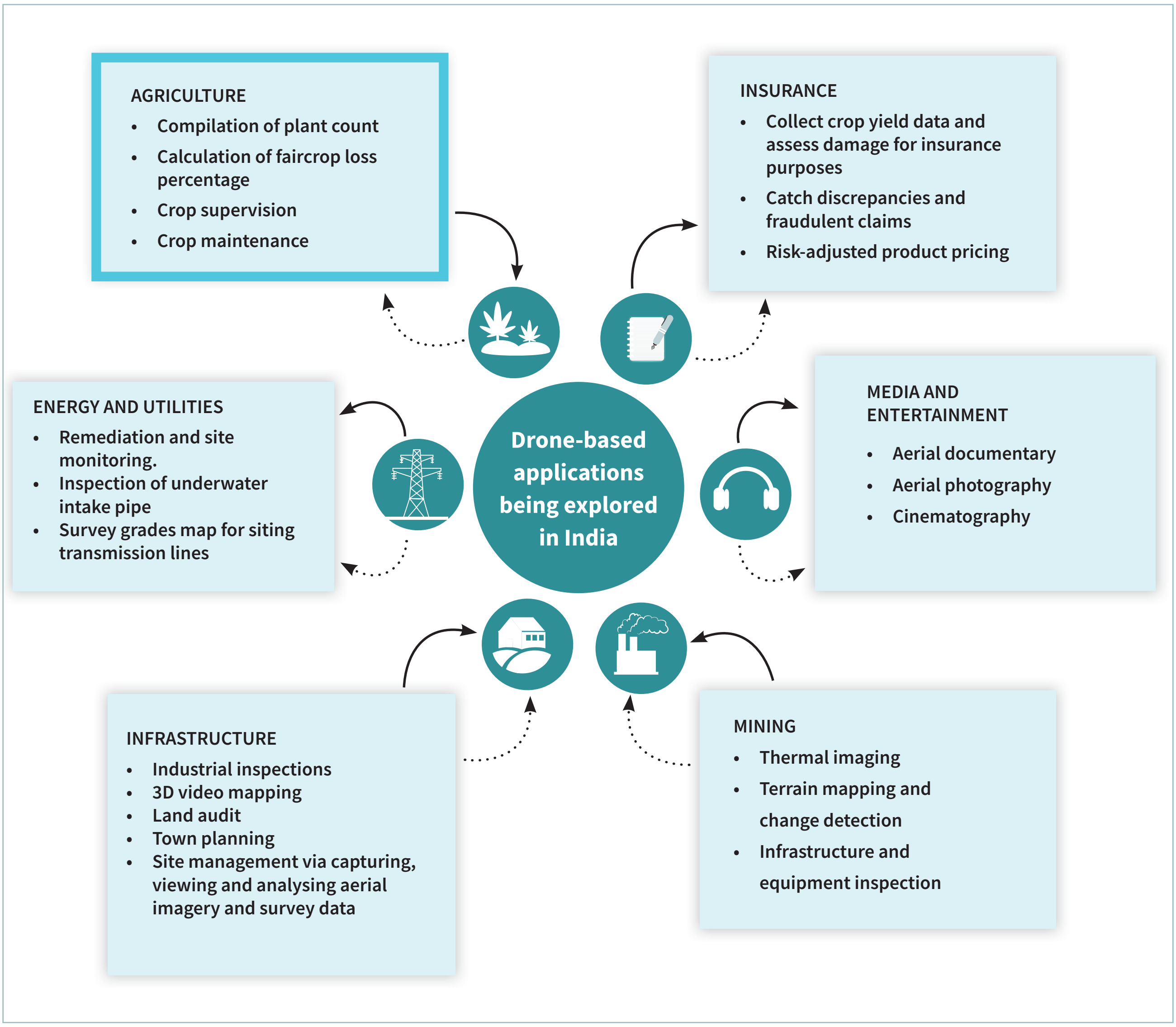
Unmanned Aerial Vehicles and Satellites

Overview

UAV or drone based technology is used in multiple industries, from defence, to agriculture to mining. In India the Unmanned Aircraft system (UAS) market is projected to touch USD 885.7 million by 2021 and the global market is expected to reach USD 21.47 Billion[8]. The use of drones in agriculture continues to grow briskly from use-cases in crop production (sow to harvest cycle) to agro-forestry, from seeding large areas, to identifying plantation growth and water and soil management. Drones are also used in animal husbandry and disaster management, where risk is mitigated through the collection of timely localised data that predicts potential disaster events. Drone sourced imaging and sensor based data is more timely and accurate than satellite based remote sensing. Additionally, the frequency and timing of collection is flexible. Drone data helps increase farm productivity and supplies data for predictive analytics and timely on-going intervention. Disaster risk assessment and risk reduction through the collection of timely localised data that better predicts potential disaster events.

[9] Ernst & Young

The PWC titled 'Data on wings – A close look at Drones in India[9] summarizes the key application of Drones below:



[9] PWC

Types of Drones

Drones may be classified in numerous ways. Categories have been tabulated and summarised below:

UAV by type	
Fixed wing	Std VTOL
Rotary wing	Single rotor Multi rotor – Bi – Tri -Quad -Octo
Size	Nano Micro Mini
Range	VLOS EVLOS BVLOS
MTOW by Vertical	<25 Kg 25-170 Kg >170 Kg
UAV by system	
Platform	
Airframes	Material category Alloys Plastics Composites
Avionics	Component Flight control Navigation Communications
Propulsion	Engine Type Power source
Sensors	Type of sensors Speed Light Proximity Position Temperature
UAV onboard software	

On-board equipment (payload)	
Camera	Type Multi spectral Hyper spectral Thermal High Resolution
Sensors	
UAV radar	
UAV Data links	
UAV Ground control	
Launch & Recovery system	

Drone range

- Flight management software & customisation - needs navigation and flight management software, mapping, data and image processing software. In addition data collection, analysis, and visualization processes requiring in-depth knowledge of plant physiology to instruct the software algorithms to recognize certain patterns which indicate plant and soil conditions.
- Optimal image processing type, and the process of correlating drone data with other metrics such as humidity, temperature, field topography, etc.
- Software & connectivity – if the region has poor connectivity cloud storage of data is a challenge, the drone must have on-board capability to store data

Using Multispectral and hyper-spectral aerial imagery creates Normalized Difference Vegetation Index (NDVI) maps, which differentiate soil from grass or forest, assist in detecting plants under stress, and differentiate between crops and even the growth-stage of a particular crop. Drones mounted with infrared, multispectral and hyperspectral sensors monitor crop health and soil conditions. NDVI data, analysed together with other indexes such as the Crop-Water Stress Index (CWSI) and the Canopy-Chlorophyll Content Index (CCCI can provide information to accurately evaluate crop health.

Satellites

Overview

Satellite based remote sensing data collection or earth observation data has been around for decades. What has changed dramatically is the improvements in image accuracy, with a continuing drop in data acquisition costs. Satellite based agro-climate data sets are available, often for free or at low cost. Providers include LANDSAT NASA, USGS, Landviewer, ESA (European Space Agency) Sentinels Scientific Data Hub, Google earth and ISRO.

Private satellite providers

With the advent of multiple private satellite providers. Micro (low orbit satellites) are cost effective and continue to proliferate the space industry landscape. Satellite technology is no more the domain of national space agencies such as ISRO, NASA, or the European Space Agency. Launch costs continue to fall, while micro satellite technology continues to increase in sophistication and capability, leading to the private sector building and operating satellites and becoming data providers through a B2B, SaaS based, business model. Applications span agriculture, mining and multiple industry sectors.

Government of India initiatives

The Government of India through the Indian Space Research Organisation (ISRO), has a significant earth observation and remote sensing satellite programme for agriculture. ISRO makes available state-specific satellite data to each state government's (State Remote Sensing Application Centres (SRSACs)), from multispectral, GIS and radar imaging and meteorological observations. The SRSAC disseminates such data to state governmental ministries.

Multispectral imaging satellites assist in crop production and yield forecasting, natural resource management and disaster management support. GIS satellites are deployed for high resolution cartographic mapping, irrigation network mapping and monitoring. Radar imaging satellites offer all-weather imaging services targeted at agriculture use cases, including flood and disaster management. Various meteorological satellites focus on weather observation and prediction.

The National Programme for use of Space Technology for Agriculture (NPSTA) is a Government of India initiative that merged the following project initiatives to form NPSTA:

- Project FASAL (for crop forecasting)
- Project NADAMS (for drought assessment)
- Project CHAMAN (for horticultural assessment and development)
- Project KISAN (for crop insurance) and Crop Intensification planning.

The programme will have four sub-programmes such as Crop Assessment & Monitoring, Agricultural Resources Management, Disaster Monitoring and Mitigation, Satellite Communication and Navigation Applications.

Remote Sensing and water management

Several applications are possible using remote sensing based technology to:

- Evaluate water bodies for algal blooms in reservoirs
- Estimate the probability of floods during the monsoon, with the resultant monitoring mechanism
- Monitor the use of water for irrigation through the estimation of evapotranspiration
- River basin hydro-met monitoring

Satellite based remote sensing is a low cost technology, mature and easily accessible. Some of the challenges include data-overload, the meshing of information collected from remote sensing with other on ground sources, and the frequency and availability of near real-time data.

As compared to remote sensing, the advantages of UAVs for Precision Agriculture is the flexibility in frequency (revisit time of satellites) and better spatial image resolution. Access through improved manoeuvrability when compared to ground vehicles. Constraints include flight planning and regulations, planned flight timing to avoid vegetation shadows that could distort imagery data. Blended use of UAV and Satellite data will provide a comprehensive solution set.

Artificial Intelligence use cases have algorithms work off remote sensing data, and but UAV based data acquisition is more accurate, granular and real-time given that a drone can be flown when required.

Many farmers have access to basic weather data available over the internet available through smartphones and via messaging on feature phones. Much of this data is available historically and real time and is harvested from weather satellites and strategically dispersed ground stations. However, the regions covered by a satellite, are high altitude, and cover large geographic regions. Weather related information is therefore common to large areas and accuracy is varied subject to dynamic changes in climatic conditions and relevance for a specific land area or crop.

UAVs (Drones) make low altitude imaging possible. The data gathered through such technology is more real time, and covers specific land areas of smaller size. A high level of detail to analyse and detect conditions for a specific plant or crop, based upon imaging and plant physiology algorithms can provide customised input at a farm level.

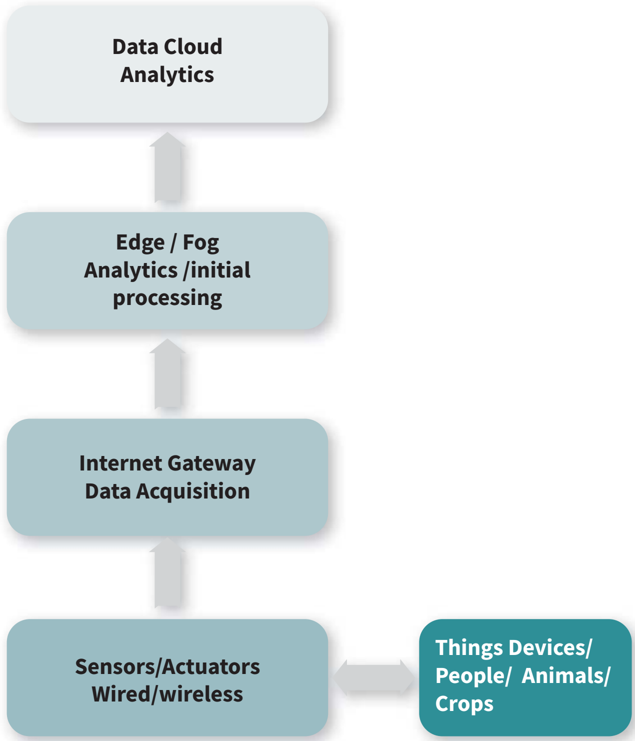
Further, ground based IOT sensors measure actual ground conditions such as humidity and soil conditions and make precision agriculture possible. Once all the data has been gathered, the same will be collated and analysed. Knowledge management and the application of Artificial Intelligence with Machine Learning (AI-ML) will transform data into powerful information models.

Internet of Things

Overview

The Internet of Things (IoT) in the agricultural context is the use of sensors and other devices to turn every action or process in farming into data. IoT is beginning to drive Agriculture 4.0. It is estimated that, with new techniques, the IoT has the potential to increase agricultural productivity by 70% by 2050.[10] One of the key drivers of implementing IoT is to reduce cost. Studies by OnFarm, USA indicate an average increase of yield by 2% in addition to the savings in energy to the tune of USD 17-32 and irrigation by 8% per hectare.[11].

Sensors are typically either "mounted" on mobile platforms such as UAV or vehicles or embedded within the ground, with the former increasingly being preferred as mobility allows for wider access. This of course is limited by the current functionality and capability of the sensor.



Device

Device functionality can be classified by its function – motion detection, position, environment -such as temperature, wind speed etc. Sensors that help in controlling other devices and logging data, and/or sensors that enable a process.

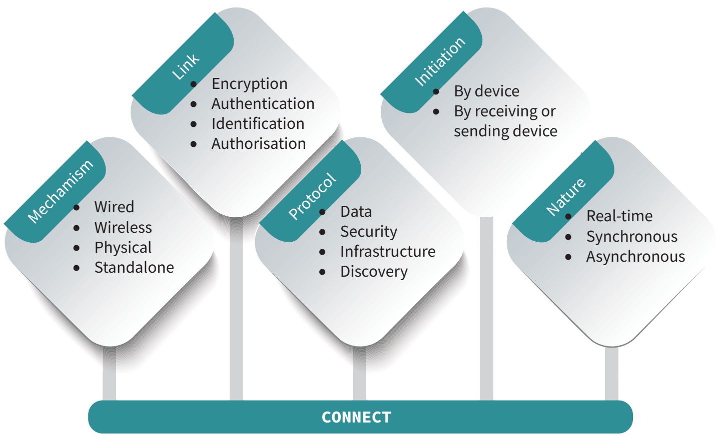
IoT devices "relate" to other devices, to processes and to systems. Standards for IoT devices are emerging. IEEE tends to be the global standard bearer for technology.

[10] Sarni, W.; Mariani, J.; Kaji, J. From Dirt to Data: The Second Green Revolution and IoT, Deloitte Insights
[11] Gralla, P., Precision Agriculture Yields Higher Profits, Lower Risks

Types of sensors

Sensor type	Application
Acoustic	• Soil cultivation, weed identification, fruit harvesting, pest monitoring
Optical use light reflectance	• Measure soil organic substances, moisture & color • Presence of minerals & clay content • Fluorescence based optical sensors used for basic plant maturity assessment
LIDAR Light detection & ranging	• Land mapping and segmentation • Identify soil type & farm 3D modelling • Monitoring erosion, soil loss & yield forecasting & modelling • Est. & identification of biomass & trees & crops • Land degradation mapping
Remote sensing	• Capture /store geographic information • Analyze & present spatial or geographical data

Connectivity modes



Modified from: The Ilot – an analysis framework, Computers in India

Key functionality in Agri-Tech

Yield Monitoring systems are placed on crop harvesting vehicles such as combines and corn harvesters. They provide a crop weight yield by time, distance, or GPS location measured and recorded to within 30cm.

Yield Mapping uses spatial coordinate data from GPS sensors mounted on harvesting equipment. Yield monitoring data is combined with the coordinates to create yield maps.

Just-in-time fertilizer tools use yield maps and optical surveys of plant health determined by coloration to regulate the delivery of fertilizers. Variable rate controllers can either be manually controlled or automatically controlled using an on-board computer guided by real GPS location.

In addition to nutrient-and-water-use-efficiencies, the technology, by reducing the amount of fertilizers and plant protection chemicals also reduce the leaching of chemicals to ground and surface water bodies and preserve the right micro-climate to improve soil health (providing immense environmental, economic, and health benefits to the society).

Weed Mapping currently uses operator interpretation and input to generate maps by quickly marking the location with a GPS receiver and datalogger. The weed occurrences can then be overlapped with yield maps, fertilizer maps, and spray maps. Drone mounted sensors and cameras are used in tandem with ground based sensors.

Variable Spraying controllers turn herbicide spray booms on and off, and customize the amount (and blend) of the spray applied. Once weed locations are identified and mapped, the volume and mix of the spray can be determined.

Topography and boundaries can be recorded using high-precision GPS, which allows for a very precise topographic representation to be made of any field. These precision maps are useful when interpreting yield and weed maps. Field boundaries, existing roads, and wetlands can be accurately located to aid in farm planning.

Salinity Mapping is done with a salinity meter on a sled towed across fields affected. Salinity mapping interprets emergent issues as well as change in salinity over time.

Guidance Systems can accurately position a moving vehicle within 30cm or less using GPS. Guidance systems replace conventional equipment for spraying or seeding. Autonomous vehicles are currently under development and will likely be put into use in the very near future.

Challenges

Challenges around technology broadly centre around skillsets available at sites, evolving standards across devices, data, transmission, poor telecom /data connectivity, coverage and data transfer rates and Cost of applied technology. In a rural setting, there could be other challenges around sensor technology which includes ruggedness of design, the ability to operate in a dust filled environment and at high ambient temperatures. Power sources for the device must be low consumption and economical. Finally, connectivity issues to networks can be challenging in remote locations.

Implementation support on would be needed with partners on ground on analysis plus data maintenance for

- Corelating the temperature levels with crop growth patterns requires an agriculture expert
- Recommendations that would be useful and actionable to the farmer and, based on their inputs, agreeing on the data required to assist the farmer in crop cultivation; and the best way for the farmer to receive the recommendation

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Photo by: DMAC PMU Ramthal

Data and Analysis Platforms

Overview

Current applications of data management and predictive analytics are making a significant impact on agriculture. Data collection, besides mechanization, at the farm level, is one of the key differences between modern and traditional farming. Valuable insights and anticipated or corrective actions improve farm management, productivity and sustainability. Data-rich agriculture, together with robotics, equipment and AI driven tools will set the landscape for sustainable agriculture through this decade.

The concept of big data revolves around five Vs.

- Volume: out-sized datasets where standard databases cannot store, manage, and analyze information
- Velocity: the capability to acquire, understand and interpret events in real-time
- Variety: multiple data formats - video, text, voice, together with complexity
- Veracity: confidence level in the quality and reliability of the data.
- Valorization: the ability to propagate knowledge and innovation

Key areas to address

The areas to address around data and platform technology cover:

- Interim and platform storage mechanism
- Data management software
- Scalability of infrastructure
- Interoperability of platforms, software and services
- Transaction scalability and throughput

V. Use of Disruptive Technologies

Overview

Disruptive technology in agriculture covers a wide swathe of technologies and uses.

Tech Area	Drones	IoT	Data & Analytics, AI	Platforms & Blockchain	Robotics	Nano bio tech
Farm Operations Mgt	Data collection – Soil/Water/ Pests Pesticide spraying Fertilizer distri.	Data collection	Evaluation & advisory	Farm based MIS Aggregation to district & State Blockchain based traceability	Fertilizer & Pesticide	Fertilizer inputs
Market Dynamics & Insurance	Insurance survey		Data inputs to insurance cover	Price; Demand Supply infor. Txn. integrity		Quality control
Water Resource mgt -Irrigation	Data collection Monitoring stock & flow	Data collection Monitoring stock & flow Monitoring quality	Evaluation and advisory	Farm based advisory	Remote access to equipment	Water quality management
Water Resource Management Command area	Ariel survey of water bodies Distribution network status	Measurement of stock & flow	Predictive monitoring of water requirements Water release depending on crop status	Command based advisory		
Animal husbandry	Herd management	Animal monitoring	Health Nutirion	Traceability		

Key objectives

- Leverage technology to empower and uplift small-holder farmers through the dissemination of knowledge, processes and inputs to implement information led farming
- Use technology to achieve scale of operations. As an example the sharing of drone services across two or three FPOs.
- Increase awareness of best practices that are targeted at a local level, through the orchestration of information from a variety of sources – govt at the state and district level, and also at a granular level of FPOs.

Agri-Tech

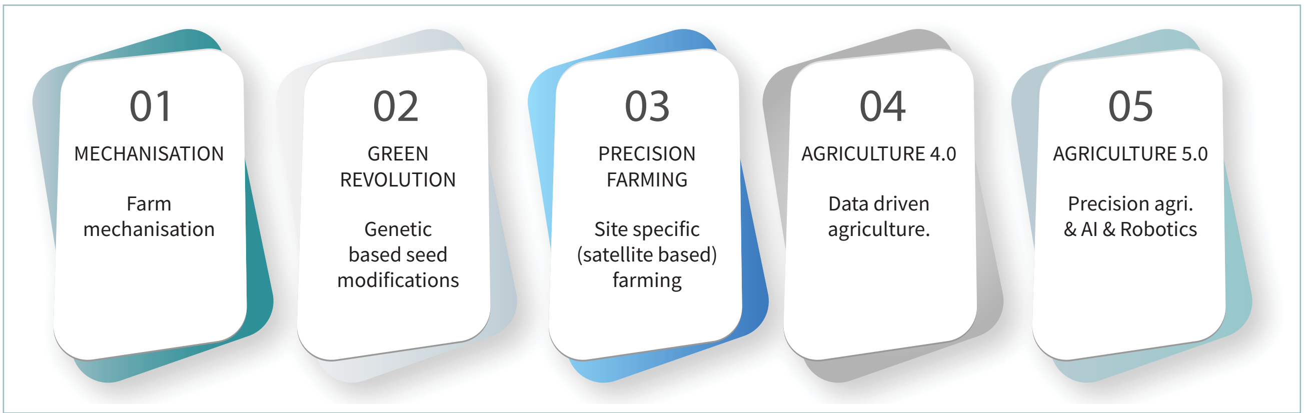
Agri-Tech in a wide sense is the innovative use of digital technology to scale solutions in agriculture, maximise productivity and profitability while increasing sustainability. Frontier technologies being implemented in Agri-Tech solutions include data acquisition and management, Artificial Intelligence (AI), nano-technology and a wide host of device and robotics based equipment. Transformation of agriculture to dramatically increase both resilience and yields is imperative as climate change and environmental destruction continue to destroy habitats. Data based farming increases efficiency and helps in environmental protection. Nations have recognised this globally, and SDG 9 – industry, innovation and infrastructure, implicitly re-enforces their focus.

Some of the outcomes of the implementation of smart farming include:

- adoption of sustainable farming technologies
- dissemination of information on best practices, farm management together with the education and training of farmers
- sharing of information, easy availability of financial resources, and increasing consumer demand

Farming and Technology innovation

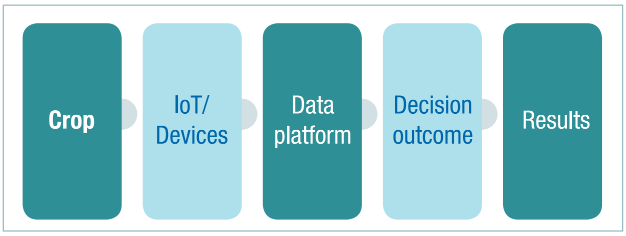
Agriculture technology has evolved over time and generally accepted milestones of development are shown below.



Agri-Tech business models are increasingly moving towards adopting a FaaS (Farming-as-a-Service) model. This enables solutions, skills and scale to rapidly reach a wider set of target agriculturists. Access to information, inputs and markets, increasing production and productivity, streamlining supply chains and reducing operational costs is enabled by the model.

The downside is the fear of another digital divide, issues around data protection, and the loss of livelihoods for labour displaced by the increased level of automation.

The scheme below depicts an Agri-Tech ecosystem for a farm.



Agri-Tech enables the management of farm variability, and also within micro areas of farms. Variability within the areas of a farm require such trends to be captured and monitored - which requires granular farm level data.

To summarise, the implementation of selective technology enables the pooling of resources (technology), expertise that is available with much wider reach – perhaps through co-operatives and Farmer Producer Organisations at the ground level.

Information technology delivers value to the farm ecosystem by enabling the connection between farmers and input vendors, together with the entire sales, marketing and logistics systems. It makes pricing and other decision making information available. Information technology also helps achieve economies of scale through the virtual aggregation of land-holdings, farm produce and agri-inputs demand management, and also provides farmer specific advisory services, information on farming best practices and commercial information.

Data Sources

Remote sensing: remote sensing services in agriculture collected through a variety of government and private satellite services. LANDSAT services in the USA formed the bedrock of this initiative and the data is available through a variety of providers such as Amazon AWS, Google Earth, NASA etc. The imagery generated is applied to analyse and monitor:

- Crop growth through the Leaf Area Index, Chlorophyll content, Stomatal activity. NDVI and NIR wavelengths
- Soil health measuring Ph, moisture and salinity t5
- Crop and weed identification
- Pest infestation
- Weather conditions – temperature, humidity, wind and rainfall conditions and predictions

A combination of spectrum evaluation and plant phenology can assist in creating newer remote sensing analytics.

Predictive analytics for decision making

Data forms the foundation for analysis. Data sources are disparate and aggregation on a common platform is key to the application of analytics. Data for the pilot will include evaluation of the following key parameters:

- Data sources – source of base data
- Data type – static or dynamic, historic or real-time
- Access method – frequency, devices etc.
- Storage – method of storage, backup, dissemination
- Data ownership, dissemination and access rights

Data sources include government base data, weather history, base benchmark data, and ongoing data collected at pilot sites through execution.

Data types here is focused around the nature of data – whether static or dynamic, and whether the data is historic or real-time additions.

Access methods addresses issues such as the frequency of access, whether remote or localised. Also considered are the types of devices upon which the data will be accessed.

Storage methods will include the database technology, and mechanisms for access and dissemination. Data backup processes will also be addressed.

Ownerhsip rights, the right to disseminate data and information together with access rights will need to be determined and codified through a comprehensive data policy.

Data – Analytics – Prediction - Actions

The implementation of data and analytics on the field typically commences with the capture of field data. The pilot primarily envisages such capture through the use of drone based sensors and cameras, together with ground based sensors. The data is then uploaded to the software platform. This then allows for farm level, granular data capture for analysis for the actual crop that is being grown. Data includes the information on soil health, crop health, water conditions, and the presence of pests if any.

Once the data is uploaded to the platform the farm advisory analytics and decision software evaluates, make predictive forecasts, and prepares a farmer advisory on the steps to be taken by farmers to improve the overall growth of the crop.

Using remote sensing, crop-based knowledge, weather forecasting as well as machine learning, we can now perform large-scale data analytics that has shown potential to optimally alter the agriculture value chain. Predictive analytics for various aspects of crop growth help improve precision and certainty in agriculture.

Artificial Intelligence and Machine Learning

AI and Agri-Tech

AI is filtering through to all areas of the agriculture value chain, from the entire crop growth cycle to logistics and marketing. AI enables the management of data for decisions in real-time water usage, weather and soil conditions. AI helps farmers to select the most productive and remunerative crops, together with an analysis of the optimum inputs required including the quality of seeds and other input resources. The predictive capability of AI enables better forecasting from weather patterns, to crop yields, the inputs and farm conditions.

Agriculture is a USD 5 Tn. USD global industry. The global AI market in agriculture was just under USD 1 Bn. in 2019, but is forecasted to grow at a CAGR of 24.8% to 8.4 Bn by 2030[12].

AI stripped down to it's constituents is a combination of two elements – the algorithms and the data that the algorithms act upon, to produce outcomes. Using drones and imaging, AI algorithms process data captured and analyse the images in near-real time to identify problem areas and corrective actions. Satellite based imagery is also used by AI systems to carry out similar analysis. However drone based data is currently perhaps more accurate given it's proximity to the ground, the ability to collect data as and when required, and the manoeuvrability a drone enables.

AI and allied technologies – neural networks and fuzzy logic implementation within AI algorithms can be leveraged to better understand agriculture data. For example a decision support system that takes input data on soil moisture, rain forecasts, temperature etc. can better estimate a watering pattern for a given crop.

AI based decisions are currently outside the scope of the pilot; however we are cognisant of their growing applicability and will incorporate theses at the appropriate stage of rollout.

Nanotech and Agriculture

The use of nano technology for sustainable agriculture is achievable through the leveraging of nano particle and material technologies to enhance crop growth and protection. Nano materials are especially productive in improving both the delivery and absorption of fertilizers, bio material and pesticides .

Nano particles used in agriculture include Silver nanoparticles for antimicrobial properties; Polymeric particles for the controlled slow delivery or absorption of agrochemicals; and Titanium dioxide particles that are used to disinfect water. Other nano particles include Zinc, Carbon for plant health and improved germination.

At the cutting edge of Nano biotechnology nano sensors are deployed for plant health monitoring real-time

Photo by: Kritsnam

decision actions. This is a brave (and frightening) new world. SMART (Singapore- MIT Alliance for Research and Technology) and MIT have done path-breaking research[13] around communication within plants, allowing for real time monitoring and action due to leaf-stress signals. In essence:

- Sensors intercept distress signals within plants to reveal how they respond to different types of stress
- Plant responses are monitored in real-time, with signals sent cell phones, allowing remote, real-time tracking
- Nanobionic approach has a range of applications including studying how to improve crop yield in urban farms
- The technology can potentially be applied to all types of plants

[12] Prescient Strategic Intelligence

[13] "Real-time Detection of Wound-Induced H2O2 Signalling Waves in Plants with Optical Nanosensors" in *Nature Plants*

Smartphone and Agri-Tech

Though this is strictly outside the scope of the current study an overview of technologies will not be complete without smart phone based technology, which is truly a game-changer for the farmer. Smart phone costs continue to drop, making affordability possible. Smart phones enable a cost-effective, and fairly accurate means to diagnosis farm and crop health. The issue of course, is one of scale, as it still presupposes the farmer walking around his field to capture data.

Standard smartphones today are equipped with several sensors that manage data capture. These include as gyroscope, accelerometer, temperature, or pressure measurement. Sensor categories include motion sensors; image sensors; environment sensors; position sensors and connectivity modems Wireless communication includes telecom providers, NFC, Bluetooth, and wireless technologies.

Smart-phone based Agri-Tech applications hold great promise for cost-effective delivery of benefits to farmers. Skills and scale however are impediments to wider implementation. The appendix explores the opportunities further.

Smartphone applications have their place in Agri-Tech solutions. Besides being ideal information dissemination devices, their capabilities today mimic much larger device collection platforms such as drones. A smartphone is power in the hands of the farmer. The benefit is that it not only acts as a device for data capture, albeit not optimal for larger holdings, but also to receive actionable information and advisories.

Smartphone Sensors and Modems	General Function	Application in Agricultural Practices
Motion sensors		
Accelerometer	Measure rotational velocity - Roll, Pitch, and Yaw axes	Motion detection (shake, tilt, etc.) to assist in the agricultural machine’s navigation
Gyroscope	Measure orientation and angular velocity	Rotation detection (spin, turn, etc.) to assist in the agricultural machine’s navigation
Magnetometer	Measure direction, strength, or relative change of a magnetic field	Create a compass to assist in the agricultural machine’s navigation
Image sensors		
Camera	Record images and videos	Image processing for objects characterization and counting
Environment sensors		
Temperature	Measure the ambient temperature	Measure the ambient temperature in the field to be used, for example, by growth, climate and pest models
Relative Humidity	Measure the ambient relative humidity	Measure the ambient relative humidity in the field to be used, for example, by growth, climate and pest models
Pressure	Measure the ambient pressure	Measure the ambient pressure in the field to calculate altitude, for example
Light	Measure ambient illuminance in lux	Measure ambient illuminance in the field to correct image colors, for example

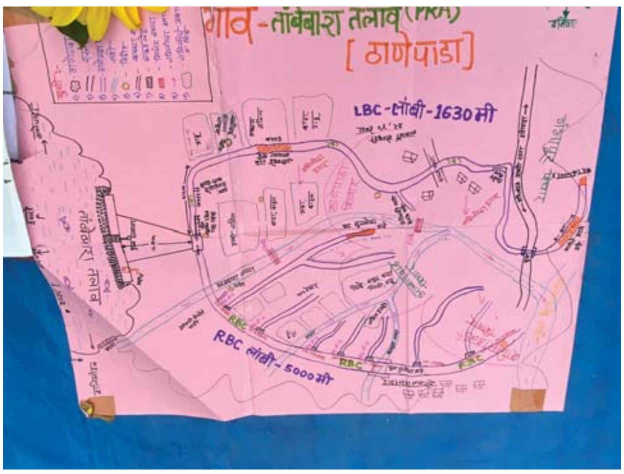
Smartphone Sensors and Modems	General Function	Application in Agricultural Practices
Position sensors		
Global Navigation Satellite System (GNSS)	Provide geolocation & time information	Geolocation of samples taken in the field and agricultural machines navigation
Connectivity modems		
Cellular network	Allow connectivity to a cellular network	Communicate with a remote server to send data and/or receive information resulting from its processing
WiFi	Create wireless local area networking (WLAN) of devices	Communicate with devices that may be scattered across the field and communicate with a remote server to send data and/or receive information resulting from its processing
Bluetooth	Exchange data over short distances	Communicate with devices that may be scattered across the field
Near Field Communication (NFC)	Enable wireless exchange between nearby devices	Read information of tags distributed across fields

Source: Agronomy

In conclusion agro-ecology, the merging of agricultural practices with the science of ecology is a vision that embraces the need for making agriculture climate-smart. But what are the risks and the real opportunities behind this vision? Could synergies between agro-ecology and digital tools be found to satisfy the needs of modernisation while ensuring the independence of farmers and a legitimate use of public funds?

Precision agriculture consists mainly of a combination of new sensor technologies, satellite navigation, positioning technology and the use of mass amounts of data to influence decision-making on farms. The aim is to save costs, reduce environmental impact and produce more food. However these processes are not ecologically sustainable. Precision farming corrects anomalies in nutrient over usage and ground water exploitation that undermines biodiversity and ecosystem integrity. In essence in a balanced agroecosystem healthy soil manages nutrients, pest infestation and works as a buffer for both pest and nutrient management.

Precision agriculture increases dependency on data and its availability in the context of small-holder farmers needs to be strengthened. Farming-as-a-Service based on open-source information can be used to share data for the common good. Sensors can help measure plant or animal needs, information can be transferred and shared among a farming community quickly, and new apps can help farmers selling their products directly and developing a more efficient community-based agriculture. The cost of specialised machines can be defrayed across the larger farming community in a district.



Pic Credit: VNV Advisory

VI. Drones Policy and Regulatory Landscape in India

Overview

The tone for the regulatory framework for Drones in India was set on August 27, 2018. The Directorate General of Civil Aviation (DGCA) issued guidelines legalizing and regulating the operation of Drones for civil use in India[14]. However, it limited the activities and operational conditions under which drones can operate. The benefits of using drones extend far beyond aerial survey and recreational purposes. To liberalize the regime further and tap the potential of drones, the Ministry of Civil Aviation (MoCA) constituted a Drones Taskforce. Based on the recommendations of this Taskforce, the Drones Ecosystem Policy Roadmap was released by the MoCA on Jan 15, 2019.

Several progressive initiatives have followed since. These are focused towards capacity building of the drones ecosystem and liberalization of guidelines. A case in point, drones were being used in a conditioned environment restricted to Visual Line Of Sight (VLOS). In May 2019, the DGCA invited an Expression of Interest (EoI) for conducting experimental Beyond Visual Line Of Sight (BVLOS) operation of drones. This paved the way for regulations allowing more enhanced operations by drones in the delivery of consumer products, medical supplies, surveillance of traffic, agriculture, construction sites, etc.

In order to be able to undertake the specific Use Cases for Agriculture (as mentioned in this White Paper) and other applications in Maharashtra, further relaxing of Drone regulations is required. The exemptions that DGCA may be required to provide from an operational perspective include:

- Permission to undertake BVLOS operations;
- Relaxation from UIN / operator permits;
- Permission for dropping / discharging items from the UAV;
- Relaxation from equipment standardization.

Policy Coverage

A gazette notification issued on 2nd June 2020 covers the following key areas:

- The categorization and classification of drones by type and by size together with their approvals
- Definitions and operations of ownership, the importing, trading and manufacture and operating of drones in the country.
- Licensing of drone providers, pilots
- Rules regarding the change in ownership of drones, and rules regarding leasing etc.
- Regulations and licences to operate drones in India
- Pilot qualifications and licences
- Regulations regarding drone mounted equipment and payload criteria
- Drone port and Air Traffic Control regulations
- Specification of training requirements

The Drones Federation of India (DFI) is an autonomous body set up to encourage the adoption of drone technology, and the promotion of the wider industry in India.

[14] Civil Aviation Requirements (CAR) for Remotely Piloted Aircraft Systems, Section 3 Series X Part I

Enabling policy and regulatory framework in India

- ***Dec 2018*** - Requirements for operation of Civil Remotely Piloted Aircraft Systems (RPAS)
- ***Jan 2020*** - Digital-Sky Platform – National Unmanned Traffic management platform that implements No Permission, No Takeoff permission commences
- ***May 2020*** COVID-19 and anti-locust operations using drones implemented and conditional exemption to Government entities for COVID-19 related RPAS operations
- ***Jun 2020*** - Draft UAS Rules 2020 released, Draft Civil Aviation Requirement for drones training released, 20,600 Drone Acknowledgement Numbers (DAN) issued, UAS Traffic Management (UTM) policy under finalization
- ***Jul 2020*** - All Green Zones (automatic permission) made live, Yellow Zones (controlled airspace) to be opened up next
- ***Aug 2020*** - DISHA Fund (Drones for Infra, Security, Healthcare and Agriculture) for research and development launched
- Beyond Visual Line of Sight (BVLOS) - 20 consortia approved and regulations in progress
- ***Feb 2021*** - Guidelines for acquiring and producing Geospatial data and Geospatial data services including Maps
- ***Feb 2021*** - Conditional exemption from Rule 15A of the Aircraft Rules, 1937 to Ministry of Agriculture & Farmers Welfare (MoAFW) for remote sensing data collection in agriculture, under Pradhan Mantri Fasal Bima Yojana (PMFBY) using drones

Use Cases Approved and Deployed

Fast Track Approvals by DGCA for mass benefit use cases

- DigitalSky Platform has started issuing online permission artifacts (OPA)
- All Green Zones made live in Jul 2020 and Yellow Zones to be opened up next.

Pic Credit: DMAC-PMU Ramthal

- GARUD ('Government Authorisation for Relief Using Drones') portal launched to provide fast track exemptions to government agencies.
- Fast track approvals given to Ministry of Agriculture, Survey of India, Maharashtra Transco, Indian Oil, state govts for drone operations - more approvals are under consideration

Use Cases in Agriculture deployed in India thus far

- Pest and Disease Control (June 2020, Telengana)

  Anti-locust operations, disperse precise quantity of Crop Protection Products (CPP)
- Soil and Field Assessment (Maharashtra, Telengana, Karnataka amongst other states)

  Create 3-D maps for soil analysis, identify dry or over irrigated areas
- Crop Health Monitoring and Yield Estimation 2018 -20 Maharashtra and Telengana)

  Image analysis to monitor crop health and estimate produce volume
- Insurance Surveys (Maharashtra, by ICICI Lombard)

  Accurately assess crop damage, reduce frauds
- Planting Seeds and Trees

  Using special instruments to plant pods with seeds and nutrients, tree saplings
- *Pesticides Spraying (not officially implemented)*

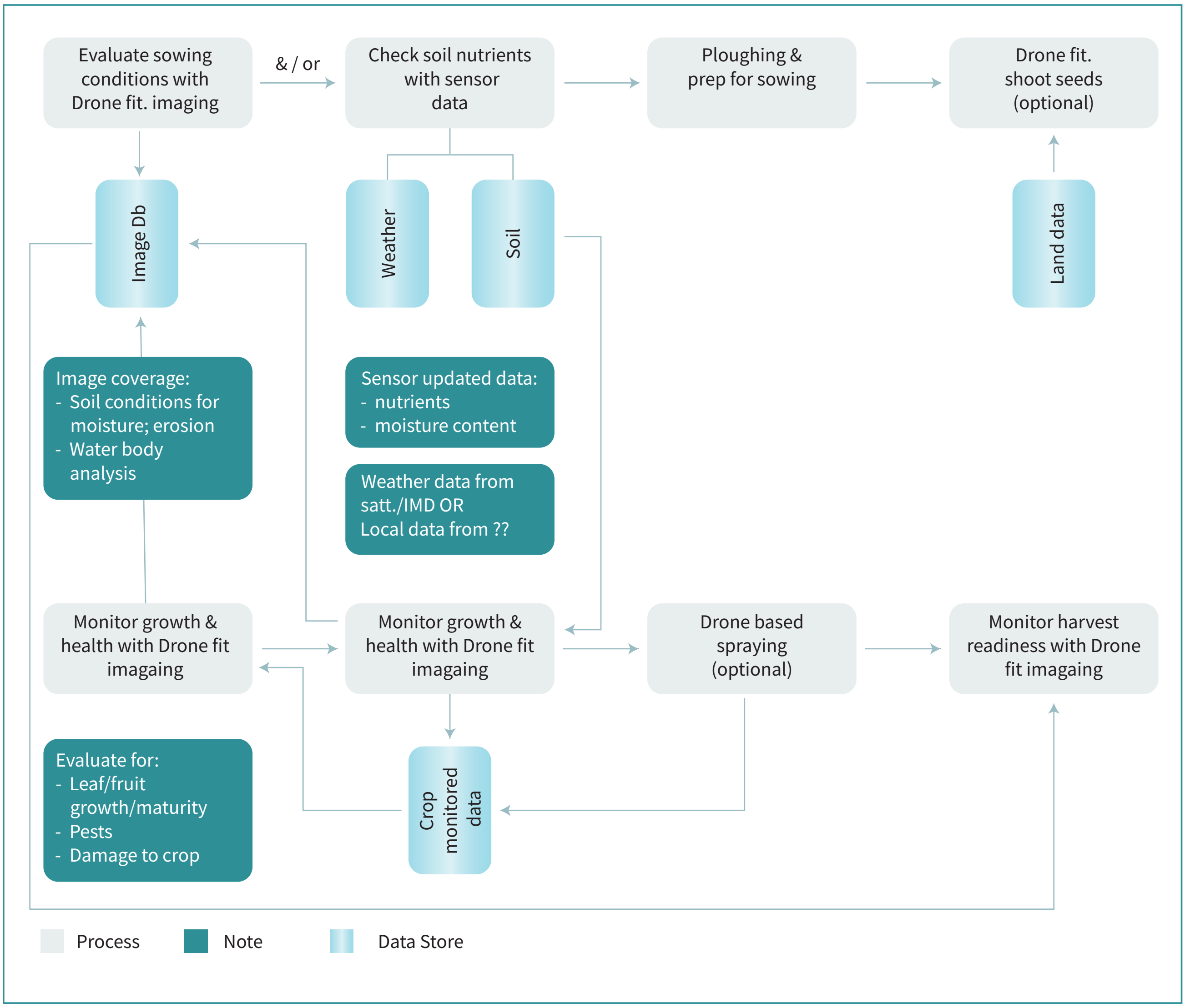
  Regulatory clearances required from multiple bodies

VII. Use Cases of Disruptive Agriculture Technologies

Four Use Cases have been identified for use of Drones in conjunction with other Disruptive Agriculture technologies as described in the previous section. The objectives, process and potential benefits for these use cases is explained in this section:

Use Case 1: Sow – Grow – Harvest cycle

Manage the growth of crops from sowing to harvesting, giving farmers inputs to optimize the yield and hence improve economic well being of the farmer



Key Objectives

- Identify the condition of the farm prior to sowing such that recommendations on optimizing sowing conditions are met
- Monitor the growth of the crop from sowing to harvest covering measurement and advisory on soil conditions, water and irrigation etc., together with appropriate management of fertilizer pest control, and weather and climatic conditions inputs.

Potential benefits

- Map area under cultivation
- Pre-sowing evaluation of soil health and moisture conditions prior to sowing, and through the cycle
- Periodic monitoring of the health and growth of crop
- Analysis of the presence of pests and other infestation
- Maturity of the crop for harvesting
- Farmer advisory on corrective action

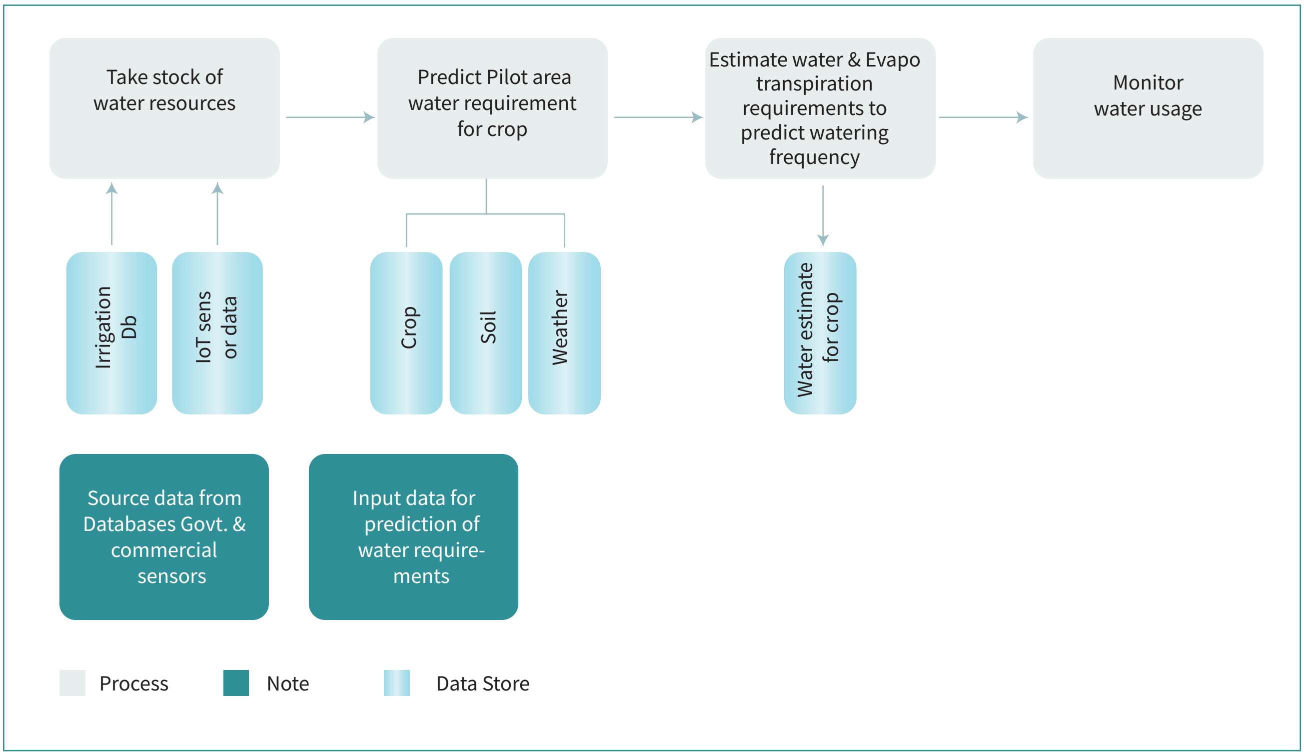
Indicative drone flights

- Flt. 1. Image capture to evaluate pre-sowing conditions – soil moisture, land contours, waste location. Additionally identify mulch etc., if relevant
- Flt2. Shoot seeds (optional)
- Flt3. Image capture of planted crop (early stage)
- Flt 4. Image capture of crop growth mid stage; check for soil conditions; pests on crop
- Flt 5. Spraying (optional)
- Flt 6. Image capture to evaluate pre-harvest crop readiness

Pic Credit: World Bank/John Hogg

Use Case 2: Smart Irrigation Management

Optimise the judicious use of water through targeted irrigation/ water release, and the conservation of water resources.



Key Objectives

- Evaluate the condition of water bodies on the farm (if any)
- Allow for the release of water to optimize crop growth and health
- Manage and measure the stock and flow of water

Potential benefits

- Monitoring stock and flow of water
- Assessment of real time water requirements of pilot farms
- Monitoring of irrigation infrastructure (canals, ponds, tanks,
- Timely release of water to optimise farmer use in crop growth

Fair value for water resource usage through pay as you use model

Indicative drone flights

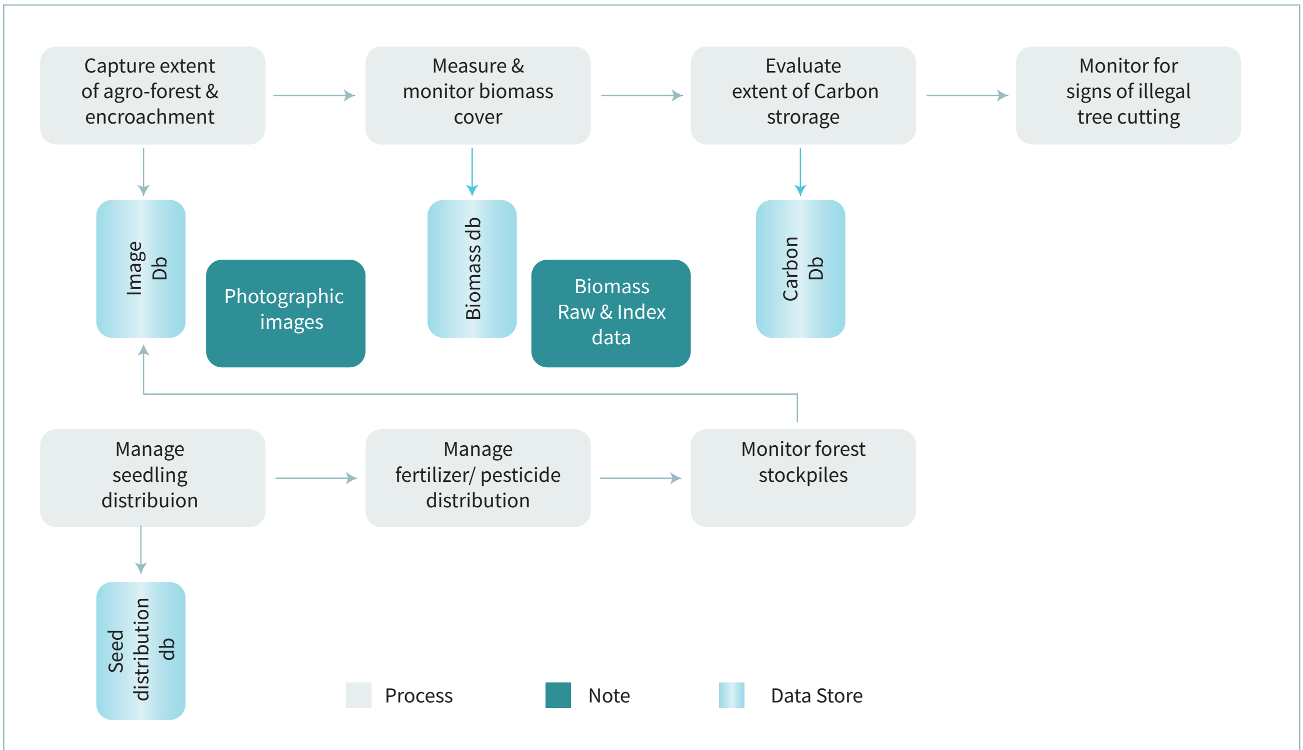
- Flt. 1. Image capture of water bodies – tanks/ bunds/ canals/ channels
- Flt2. Image capture of fields that have been irrigated for moisture – planted crop (early stage)
- Flt 3. Image capture of crops –mid stage and water requirements

Pic Credit: 2030 WRG

Pic Credit: 2030 WRG

Use Case 3: Precision Agro-forestry

Harmonize land use and it's conservation, improvement in soil and water conservation initiatives, and the increase in biomass through greater afforestation.



Key Objectives

- Identify land usage patterns and classification, the extent of denuded land, and the reforestation acreage under consideration or that is being actively managed
- Map ground data including the contours of the land, acreage, soil and water body data
- Monitor the growth of the plantation from sowing to harvest. This includes measurement and advisory on soil conditions, water and irrigation etc., together with appropriate management of fertilizer pest control, and weather and climatic conditions inputs.

Potential benefits

Plantation

- Land classification – whether degraded, forest etc., and type of usage
- Mapping forest extent, biodiversity, & presence of human habitation within the forest area
- Agro forestry – measure the extent of canopy cover, number of trees canopy gaps & height
- Seedling planting through drone technology
- Monitoring of illegal cutting and quarrying
- Measuring forest produce stockpiles
- Crop health

Carbon

- Measure the extent of carbon sequestered in biomass through 3D mapping

Soil

- Health and mineral deficiencies
- Soil moisture conditions
- Distribution of fertilizer & pesticide

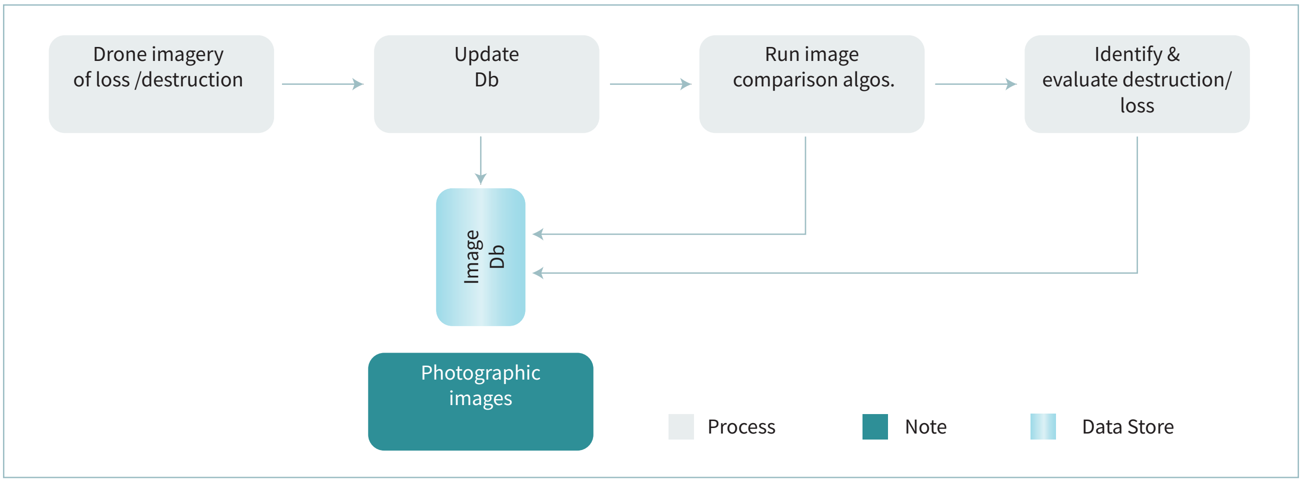
Water

- Water stress – availability and usage

Pic Credit: VNV Advisory

Use Case 4: Agri-Insurance Claims Management

Assess and evaluate claims damages.



Key Objectives

Potential benefits

Use drone flights to assess the damage from floods, drought, pest infestation on a farm where the damage has occurred:

- Estimate the area impacted
- Estimate the damage or loss and attribute an economic value
- Drone flight over the damaged areas to collect the data.
- Use drone mapping software to process and visualize the data in order to measure the crop loss
- Using field boundary features, map the field to make the assessment even easier
- Lowers the cost to the service provider by reducing frauds and information asymmetry

Pic Credit: VNV Advisory

VIII. Pilots

Overview

The following clear principles from corporate experimentation are followed for a successful execution of the pilot. Innovation is often looked at through the lens of high impact outcomes, but are more often than not the sum total of smaller focused ideas that are implemented.

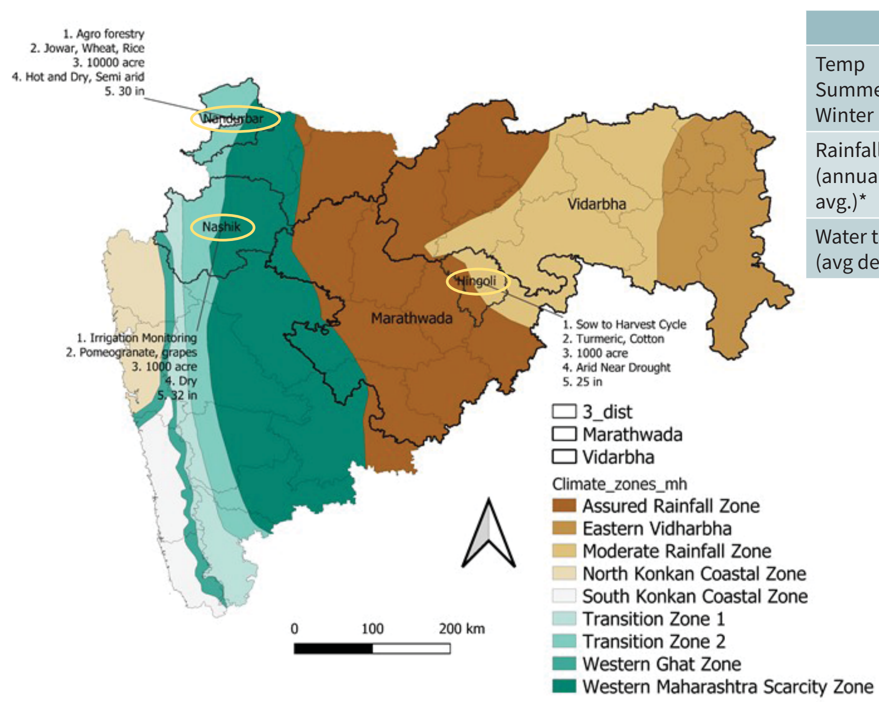
Therefore, the following needs to be ensured:

- Defining testable hypotheses
- Stakeholder commitment to accept and work with the outcomes
- Practicality of the experiment
- Processes to ensure reliable experimentation and results
- Ability to monitor and capture “cause and effect”
- Value measurement of the experiment

Three potential locations have been selected for the pilot execution, Hingoli in Aurangabad district, Nandurbar District and Nashik within the Nashik district in Maharashtra.

The selection criteria include:

- Accessibility: accessibility to the pilot location for various stakeholders and the wider pilot team so as to execute to plan
- Climatic conditions: three regions within Maharashtra with fairly diverse climatic and socio-economic conditions have been identified. Aurangabad district is water stressed, the agriculture is mainly rain-fed, and is arid with drought conditions prevailing. Nashik on the other hand has access to irrigation as the river Godavari flows through the district. Nandurbar is a tribal district with agro-forestry being implemented.
- Crop mix: the locations farm grains and horticultural produce, together with a diverse range of crops, vegetables and fruit. Nashik is known for it’s Grape vineyards and Pomegranate orchards
- Agro-forestry: Nandurbar has specifically been chosen for the agro-forestry initiatives undertaken by both the Govt. of Maharashtra and public-private partnerships



	Hingoli	Nandurbar	Nashik
Temp Summer H Winter L	42 C 12.5 C	41 C 14 C	36 C 12 C
Rainfall (annual avg.)*	25 in	30 in	32 in
Water table (avg depth)	60 Metres	39 Metres	9 Metres

- Irrigation and rainfed areas: irrigation networks are prevalent in the Nashik district, whereas Hingoli is primarily rainfed.
- Water table levels: across India the reducing rate of groundwater depletion is a vital challenge to successfully achieve climate resilient agriculture. Given the state of groundwater in the Hingoli area we look to measure whether our interventions can relieve some of the pressures on groundwater.
- Localised data availability: local data at a farm level, with a fair level of accuracy is key for the success of the pilot. This includes crop data yields per acre, and the quantum and cost of inputs such as fertilizer, water, seeds etc.
- Local partners and adoption: we evaluated the availability and enthusiasm of local partners to work with us on the pilot as being key attributes. Additionally, we have evaluated their ability to adopt new practices, technology and the receptiveness to moving towards an Agri-Tech paradigm of farming.
- Connectivity & infrastructure: the availability of telecom networks together with a fairly stable source of power

Process

2030WRG, along with inputs implementation support from the Department of Agriculture Govt. of Maharashtra and implementation and funding support from local bodies and private partners will execute the pilot. The 2030WRG team will act as the primary single point of contact and co-ordinator for all stakeholders.

	Nashik	**Hingoli**	**Nandurbar**
Pilot location	• Nashik – basin of the Godavari, relatively well irrigated • Horticulture cultivation – with a 9 month cycle time • Fairly advanced farming methods	• Cash and traditional crops • Turmeric – 4 month cycle time. A good cash crop example to model • Presence of PoCRA (World Bank funded project	• Nandurbar district – a mix of rainfed and irrigated farms • Tribal • Key crops include Jawar, Wheat, Rice
Climate	• Hot and dry	• Arid, near drought conditions	• Hot and dry
Groundwater availability	• Poor	• Highly stressed. Table nearly drained	• Poor
Irrigation status	• Fairly well developed, given Godavari command area.	• Mainly rainfed area	• Mixed – both rainfed and irrigated
Size	• 1,000 acres	• 1,000 acres	• 2,200 acres
Crops	• Pomegranate • Grape	• Cotton • Turmeric	• Agro-forestry plantations
Partners	• Sahyadri Farms • NABARD • Kritsnam • MPKV Rahuri	• PoCRA project area • Bharat Agri • FPO – Mr. Chavan • NABARD • Kritsnam • MPKV Rahuri	• DSC • VNV Advisory • NABARD • Kritsnam • MPKV Rahuri

Challenges

- Data: data is of paramount importance through each stage of the execution of the use case. Data requirements broadly include:
  - Weather and micro climate data
  - Farm input data, – soil conditions, water availability, fertilzer and pesticide usage data

  This data is both static(historical), and dynamic – as collected through the execution of the pilot
- Multi-cropping carried out in the Hingoli area, which poses a challenge for drone based surveying. Different crops will require identification.

Key outputs

- Estimation of crop acreage under production
- Crop yield predictions and comparison with past seasons
- Weather predictions, comparison and corrective actions
- Crop growth and health through the sow to harvest cycle
  - Soil monitoring
  - Fertilizer inputs
  - Disease and pest identification and corrective action

Imaging outputs

The following key outputs from the drone flights and satellite imagery will be collated and delivered by our drones service providers for further analysis:

Normalised Difference Vegetation Index (NDVI)

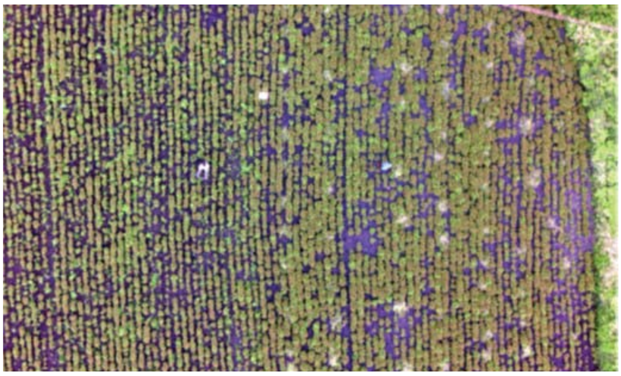
- Chlorophyll sensitive, measuring plant health through the reflection of light at certain frequencies
- Measures the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs)
- NDVI helps differentiate vegetation from other types of land cover and hence understand the land use changes. It also helps vizualization of vegetated areas and detection of abnormal changes in growth of the crop

Enhanced Vegetation Index (EVI)

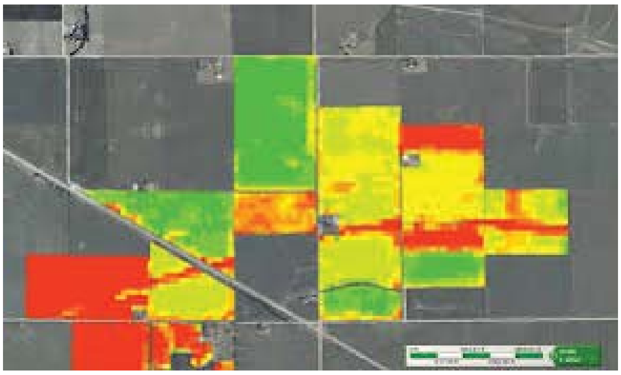
- 'Optimized' vegetation index boosting the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring, by de-coupling of the background canopy signal and a reduction in atmosphere influences
- Identifies structural variations in the canopy and plant physiognomy
- EVI is used to quantify evapo-transpiration and water-use efficiency, or assessments of change in crop health/stand

Canopy chlorophyll Index (CCI)

- Two-dimensional remote sensing index, derived from the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Red Edge (NDRE)
- Is a canopy nutrition control measure that enhances the process of precise fertilizer application
- Used to detect the Nitrogen availability and/or extent of deficiency in crops that will directly determine biomass, carbon storage potential and hence the yield from agro-forestry plantations.



Stacked Multispectral images



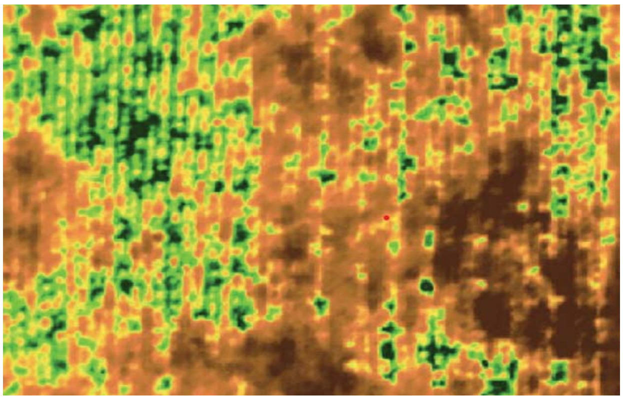
Normalised Difference Vegetative index (NDVI)

Enhanced Vegetative Index

Canopy Chlorophyll Content Index

Water Stress Index (WSI)

- Quantifies water stress and helps schedule irrigation
- The difference in crop canopy to air temperature and AVPD is used to build a non-stressed baseline equation and hence the CWSI
- The WSI helps monitor and quantify water stress and in irrigation scheduling



Crop Water Stress Index

Working with the Indices

IoT based output

We are currently evaluating the feasibility of augmenting and satellite based based data collection with targeted ground sensor data. Devices will be used to track stock and flow of water, and to measure the availability of water in ponds and wells.

Platform analytics and output

Our current thinking is to work with Bharat Agri our partner around ground based data collection and use the platform they provide to collect and analyse data.

Bharat Agri has a cloud-based platform that is hosted on the Microsoft Agri-Tech platform FarmBeats. This allows for further analytic and predictive software.

We have approached risk analysis in a pragmatic manner, looking to analyse risks to the pilot, and group them into project (macro risks), Technology, Financial, Skills & Implementation risks.

Key Risks

Key risks related to the location, finance, technology, human resources and general implementation are tabulated below:

Risk
Project / Location of pilot
Characteristics of site to allow for smooth pilot execution – contiguous land; Cropping pattern; general farm & economic landscape
Mobilising Farmer & FPO buy-in & involvement
Local Institutional support
State Govt support
Technology
Technology adoption capability & speed
Regulation & policy around drones
Local Connectivity
Local infrastructure & power availability
Technology partners ability to service the pilot area
IoT sensors cost & servicing
Drone service experience in Maharashtra
Financial
Ability to sustain payment
Project financing
Cost
Cost overruns
Skills and Learnability
Skills gap
Infrastructure to learn & share best practices & results
Implementation
Pilot conversion
Project execution/ delivery
Cost over-run
Meeting target Outcome & CSF

Critical Success Factors

An understanding of factors critical to the success of the pilot together with measurable metrics are important to identity the longer term impacts of the potential project:

Overarching factors

- Easier access and lower cost of capital to the farmer, i.e. a lower rate of interest
- Lighter footprint on factors of production leading to climate resilience and the lowering of environmental impact
  - Lower water consumption
  - Lower fertilizer inputs
- Recharging the water table
- Rain water harvesting and storage through bunding, the development of ponds etc.

Key objective	Critical Success Factors Cause of success
Project	
Project sponsorship	Partner – PPP sign up
High Stakeholder buy-in, alignment & commitment	Greater farmer, FPO, Dist. authority involvement
Improved mgt. of watershed & irrigation resources	Increase in area covered, with lower water used per acre
Increased implementation of drip-irrigation	Increase in area under drip irrigation
Improve in rural development & quality of life & women empowerment	Increase in farm incomes Increase in women participation & income
Increase in agriculture productivity	Higher Yield per acre Lower crop wastage
Knowledge building & dissemination of benefits & results	District Agri. Colleges, FPOs, Dist. Authorities Farmer adoption of advisory service
Operational	
Productivity increase through reduction in time and effort	For each process (Field prep.; Monitor Growth; Harvest) reduction in manpower & elapsed time
Reduction in losses due to pests	Time-series of Crop loss attributed to pests
Yield increase due to Fertilizer input & quantum of natural fertilizer used	Fertilizer quantum used per acre & imputed yield increases
Financial	
Total cost of ownership of drone based process	Cost for each process covered vs. existing cost for process
Technical	
Cost effective implementation	Collaborative model to drive down cost
Indigenisation	Level of local/localised technology
Implementation evaluation on Time, Cost, Financial benefit	On-time execution on agreed milestones
Pilot	
Partnership Success and Stakeholder Management	Stakeholder feedback
Pilot conversion to Production	Adoption by districts
Meeting of stated cost-benefit goals	To be finalised
Adoption at pilot sites	No. of Farmers / FPOs adopting the technology and advisory

Cost-Benefit analysis

While costs are easier to identify and define, benefits accrue through a number of inter-related factors. An attempt to identify and quantify key factors will be carried out. A caveat is that this is not an exact science, and that benefits cannot be attributed directly in isolation.

Benefits can be broadly classified into:

- Agri-water based interventions
- Technology interventions
- Market interventions

Agri-water interventions[15]:

- Seeds quality
- Fertilizer quality
- Crop diversification – from mono cropping to high value crops and inter cropping, leading to sustainable productivity growth through increased crop intensity
- Diversification towards water efficient crops that lead to re-charging of the water table
- Soil health - The Soil Health Card (SHC) scheme by the Government of India provides an assessment of soil quality and corrective measures that a farmer should adopt to obtain a better yield. Andhra Pradesh, Punjab and Tamil Nadu have implemented the scheme. The programme will develop processes for soil sample collection, sampling norms, quality control in the soil analysis, training of sampling staff and lab personnel, and the enabling information technology.

Technology based interventions:

- Even and denser seeding
- Targeted fertilizer inputs saving on quantity, and dosing where needed
- Targeted pesticide delivery saving on quantity and dosage
- Better weed and pest management through identification of such occurrence

Market interventions

The approach to analysis will be to broadly take the following major inputs to the agricultural process and look at the costs and perceived benefits.

As an example:

- We have assessed each key input element of cost per acre at the local district level
- Calculate the cost saving achieved through the technology intervention. For example:
  - Use of less fertilizer due to targeted consumption
  - Less consumption of pesticide
  - Labour saved for each process due to automation
  - Water savings due to more targeted irrigation

[15] Summarised from Dr. Surabhi Mittal, Benefits & Costs of Agriculture in Rajasthan

IX. Pilot Execution Plan

Overview

Pilot Management

Programme Management

- 2030 WRG as secretariat to the Maharashtra-MSP on water, will offer supervisory oversight to program management together with stakeholders identified.
- Primary role will be that of co-ordination between the various stakeholders, monitoring progress of the pilot and weekly monitoring against plan
- Reporting to the Project Steering Committee and Project Sponsors
- Secure buy-in and ensure linkages for uptake and increased adoption

Key stakeholders for Pilot

- Maharashtra-MSP on Water, supported by 2030 WRG
- DGCA, Ministry of Civil Aviation, Government of India
- Dept of Agriculture, Government of Maharashtra
- Dept of Water Resources, Government of Maharashtra
- Department of IT, Government of Maharashtra
- MWRRA, Government of Maharashtra
- PoCRA
- NABARD
- MPKV, Rahuri
- VNV Advisory
- Samunnati
- Bharat Agri
- Kritsnam Technologies
- Drones Service Providers (under discussion)
- Nishith Desai Associates
- Local administration of the respective districts

Timelines

- The timeline for the pilot is to cover the Kharif and Rabi season over 2021 -22
- The pilot will extend beyond the season as data is assimilated, analysed and conclusions drawn

Indicative Cost of the Pilot

Indicative operating costs for the pilot at 3 potential locations are approximately INR 2 Crore (USD 273,972).

Indicative Costs: Hingoli & Nashik Pilots	INR Lakh	USD
Advisory & platform / dashboard fee	17.0	23,288
Drone flights	120.0	164,283
Other operating costs	14.0	19,178
Total	**151.0**	**206,749**

Indicative Costs: Nandurbar Pilot	INR Lakh	USD
Advisory & platform / dashboard fee	17.0	23,287
Drone flights	22.0	30,137
Other operating costs	4.0	5,480
Total	**43.0**	**58,904**

Assumptions

- Coverage: 1,000 acres for each of the pilots at Hingoli and Nashik; and 2,200 acres at Nandurbar (Agro forestry)
- Approximately 10 drone flights across the crop growth cycle (Hingoli and Nashik); and 3 for Nandurbar (agro forestry)
- Exchange rate assumed at INR 73 to 1 USD
- On-ground sensor cost for pilot will not be significant to change the costing. This will be included as a Capital item for production rollout
- Exclusions
  - Satellite image data - assumed to be at no cost for pilot
  - Travel etc.
  - Capital investment in micro-weather stations

Pilot Playbook and Governance structure

The pilot playbook sets out the overarching management, monitoring and execution of the pilot. For each "phase" of the pilot we have enumerated the key activities. Further granular detail is provided in the project plan. Both documents here are indicative, and will be refined as we go into the pilot phase.

During the planning phase organisation, governance and reporting mechanisms will be defined and agreed upon by all relevant stakeholders. We will scope the execution of the pilot, defining the boundaries, the process to be followed together with reporting and monitoring templates. We will also define budgets and cost management processes.

During the setup phase the technology partners for the pilot will setup and integrate the necessary components. In essence this will cover the drone service provider and/or the data platform and analytics providers. Local partners will also need to integrate during this phase.

Communication both internal – with all stakeholders and actors, as well is external communication to the local farmers, administration etc.

Execution of the pilot will cover the actual data capture, farm advisory and predictions. Tracking of all outcomes, the issues and key risks.

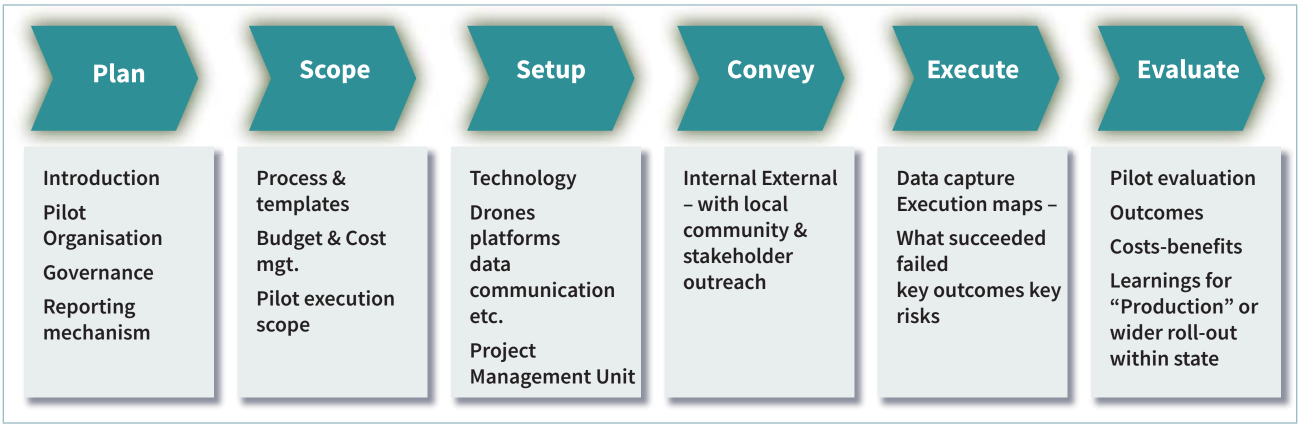
Evaluation of the pilot – measuring the outcomes against plan will cover the costs and benefits, and the measures of critical success factors defined.

For the pilot the following governance structure will be followed to manage and guide the project:

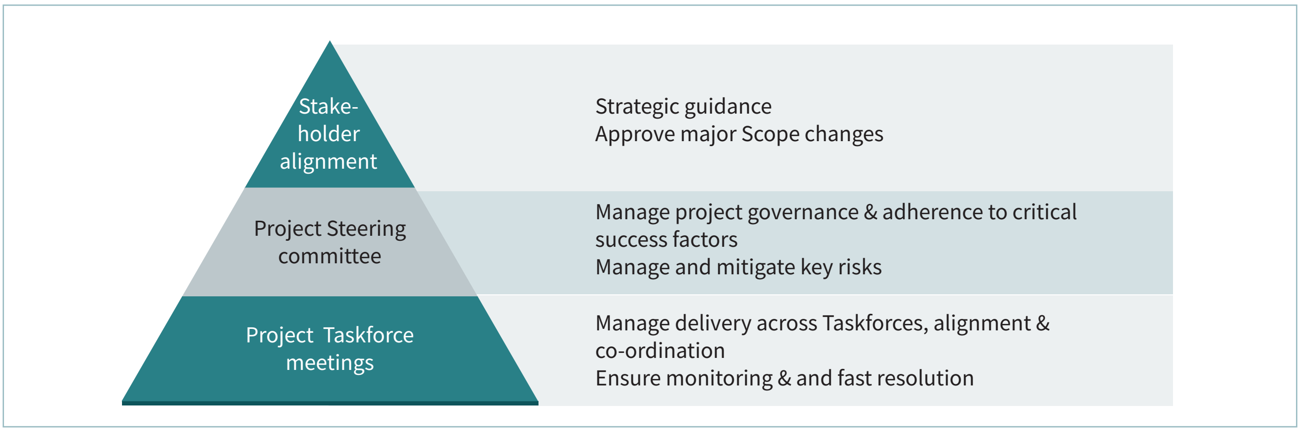
Project workstream meetings will be weekly, in order to monitor and co-ordinate each workstream, ensure they are aligned and working to plan.

The project steering committee will oversee the operational focus and progress of the pilot, and will be responsible for the overall implementation of the pilot.

Pilot Playbook



Pilot Governance



Stakeholder alignment will consist of key stakeholders who provide strategic guidance to the pilot, ensuring that it meshes with wider objective, and will have the responsibility to approve major changes in scope if required.

Indicative Project plan - Steps

PILOT: PROJECT PLAN

PRE-PILOT PLANNING

- Local stakeholder on-boarding
- Finalise roles -responsibilities
- Define project monitoring & metrics
- Agree Stakeholder reporting
- Setup of site office
- GoM & DGCA UAV permissions
- COVID permissions (if required)
- Pilot review meeting mechanism & setup

PILOT OUTREACH

- Evaluate infrastructure - telecom/power
- Local communication/buyin about pilot
- Agri. University outreach

PROJECT KICK-OFF

ON-SITE SETUP

Identify acerage, owners, FPOs, Agri Uni.

Data

- Validate farm level data availability
- Data source, access etc.
- Installation of micro weather stn. at site

Platform

- Establish platform connectivity
- Define Update mechanism
- Data - schemas / mapping /access ......

ANALYTICS / ADVISORY POTENTIAL DEFNS.

Operational

- Define Crop data capture
- Define Growth data capture
- Define Fertilizer data capture
- Define Pesticides application data
- Define Irrigation or moisture data capture
- Pest infestation data
- Harvest data

Field

- Soil health
- Labour
- Machinary

Farm

- Local weather & climate
- Yield & productivity

DRONE FLIGHT PLANNING

Flight 1

- Key data collection requirements
- Update - local & cloud
- Analysis
- Analytics runs
- Predictive & advisory outcomes

Flight 2

- Key data collection requirements
- Update - local & cloud
- Analysis
- Analytics runs
- Predictive & advisory outcomes

Multiple flights... n
(dependent on conditions on ground)

PILOT EVALUATION

X. Production Rollout

Overview

The roadmap post the pilot the rollout of a drones, satellite and and IoT based data acquisition service to farmers (at the level of FPOs), together with a farmer advisory service to enable improved agricultural decision making. The pilot aims to identify the cost-benefits, operational and scalability issues and corrective actions, to form a comprehensive execution strategy.

In order to implement agritech in Maharashtra successfully the following landscape needs to be understood and addressed.

Diverse Agro-climatic conditions

Maharashtra has diverse agro-climatic conditions, differing levels of water stress, and wide crop varieties. These need to be mapped and covered as the pilot is extended.

Multi-stakeholder collaboration

The bringing together of stakeholders that have worked on the pilot to scale for a state-wide rollout is a significant undertaking. All actors need to be mindful of organisational realities and objectives, and that these could come into conflict at times. This is a reality in public-private partnerships of this scale, and must be addressed openly to achieve long term success.

Areas of Validation

A vital outcome from the pilot will be to fine tune and build out the following areas that are imperative for the long term success of the initiative.

- Business model
- Technology
- Policy interventions - harness innovation
- Financing mechanisms – how govt , funding agencies NGOs etc can assist

Business Model

Farm as a Service (FaaS), a collaborative pay as you go model is the only truly viable model for a predominantly small-holder farming environment. For the farmer this will enable the pooling of resources, increase purchasing and negotiating power. For the suppliers of inputs and services this allows for significant operational size, bringing economies of scale into play.

Farming as a Service model is being envisaged as part of this project. FaaS allows access to usage of an asset on Opex basis rather than on a Capex basis. The asset in consideration here is information that is required by the farmer for improving crop yields, increase water use efficiency and maximizing the impact of agriculture inputs

The FaaS platform will be created to amalgamate the data that is available from remote sensing satellites, UAV /Drones to create a data superset upon which agricultural information models can be built. The platform itself further utilises cloud based technologies for effective collection, storage, analysis and dissemination of information to farmers. A multi-stakeholder group will make the creation of the platform possible, from regulatory, to government, to technology companies, drones service providers, agri-techs and farmer co-operatives. Financial viability has been envisaged through funding strategies using Results based financing models including carbon finance, blended finance, rural infrastructure development funds and the like, executed by Agri-NBFCs, social enterprises and FPOs.

The farmers will therefore need to only pay for services specifically subscribed by them, and should be able to measure commensurate improvement in crop yield. Financing models to further make affordability and farmer participation could include performance based subscription models, wherein farmers pay on a revenue sharing model only if there is an actual improvement in yield.

Technology

To scale technology to significant levels will require standardisation. A viable technology stack that defines multiple components across the value chain need to be developed and agreed. Within this partners can play individual roles, though we forsee a certain level of committiment.

Technology covers an extremely broad swathe of hardware, software, platforms, devices, equipment, communications etc. An indicative high level list would include the following:

Hardware & Infrastructure services	Computers; platforms Infrastructure providers IoT devices
Software & tools	Operating systems
Equipmment	Drones RFID (if relevant)
Communications	Protocols Data backbone Last mile connectivity
Data	Ownership - Source data & data results from inference engines access

Key principles that will be followed include:

- Interoperability
- Open architecture
- Scalability
- Traceability

Ecosystem Enablers

Startup & Innovation ecosystem

India's startup system is seeing a proliferation of incubators and accelerators. The positive impact has been an increasing number of agri startups. Incubators range from global bodies such as IFC, the UN, to universities such as the IITs' to private incubation facilities.

Linking startups to the direct beneficiaries or clients – in this case the farmer, or more realistically the Farmer Producer Organisations (FPO). This facilitation is a key objective as the pilot is rolled out and implemented. The pilot envisages working with both startups and global firms, and will endeavor to cross-seed ideas and technology.

Ecosystem policy interventions

Policy interventions to encourage, incentivise and reward implementation af agritech based sustainable farming and water conservation practice. These will cover:

- Improved inputs – seeds, fertilizer etc.
- Implemtnetaion of sound ecological practices – including natural fertilizer, natural seeds
- Improved water conservation and water management
- Improve non-invasive farm practices
- Support for collaborative FaaS business models that allow farmers to pay only for the services they use, and when they "consume" them
- Financing and credit that incentivises farmers to adopt such practices
- Insurance benefits through lower premiums for agritech innovation

Enabling infrastructure

- Training
- Awareness building
- Financing for agritech implementation

Project Management

Methodology – the implementation of Agile principles at scale. Not only is this innovative, but enables the breaking down of a significantly complex project into manageable size, with on-going performance measurement and course correction.

The roadmap envisages the rollout of a drone and IoT based data acquisition service to farmers (at the level of FPOs), together with a farmer advisory service to enable improved agri decision making. The pilot aims to identify the cost-benefits, operational and scalability issues and corrective actions, to form a comprehensive execution strategy.

Appendices

Appendix I: Partner Evaluation Criteria

Technology partners have been evaluated along the following broad parameters.

Technical	
	Scalability
	Open environment
	Interoperability & integration
	Communication protocols supported
	Support & Service model; SLA; Pricing
	Professional support /helpdesk
Drones	
	DaaS model & capability
	Govt. empanelment
	Licences & other regulatory Clearances (incl. for pilots)
	Agri-Tech experience & Applications
	Drone equipment
	Imaging equipment
	Drone category for deployment
	Drone systems specifications
IoT Sensors (for Agri-Tech)	
	Local /imported sensors
	Power source
	Ruggedness – operating tolerances
	Functionality
	Connectivity
	Standards supported (if appl.)
Platform	
	Platform architecture
	Connectivity mechanisms
	Platform integration
	Data access, control, backup etc
	Data security
	Source device connectivity
	Protocols
	Agri suite - functionality* incl. analytics
	SaaS models of payment for usage; storage; analytics etc.
	Mobile connectivity & devices Compatibility
	Fault tolerance/ failover control
	Edge computing

** Functionality includes use case coverage, ease of use, value, etc -evaluated separately*

Functional experience	
	Agri-Tech experience
	India deployments & experience in Maharashtra
	Platform connectivity experience
Commercial	
	Total cost of ownership
	Payment models
	Capital or Operating weightage
	Pilot cost
	Long term viability as a partner
	PPP experience
	Financial reputation
Reputational	
	Partner compatibility
	Reputation

Appendix II: Examples of Global Use Cases

AI based advisory

Company: ConserWater
USA

Application: AI and satellite based agro-advisory predictions

Objectives:

- Advisory services across the growth of a crop
- Predictive analytics based on deep learning and AI to improve decision making on soil conditions

Key leverage:

- Satellite based data source, allowing for global (anywhere) use coupled with AI to provide farm advisory to any size of farm anywhere
- Proprietary deep learning algos to predict soil moisture, nitrogen and phosphorous etc.
- Satellite data from NAS, JAXA, ESA and private providers
- Soil depth predictions from 10 cm to 40 cm

Drone implementation

Company: DroneSeed
USA

Application: Drone based seeding for afforestation

Objectives:

- Drone based delivery of seeds especially in remote inaccessible areas
- Scaled operations

Key leverage:

- Estimated that seeding is six times more effective through drone based seed delivery
- Use of "seed pods" (seeds wrapped in soil) that a fired into the soil to the required depth

Livestock Monitoring

Company: Allflex
USA

Application: Livestock monitoring

Objectives:

- Data driven management of animal husbandry
- Improve the health and wellbeing of animals, while optimising production output
- Improve the quality of livestock over time and manage the outbreak of disease etc.

Key leverage:

- Collar based tags to identify individual animals
- Animal health monitoring through the delivery of temperature, health, activity and nutrition insights
- Data to better manage livestock including for veterinarians, regulatory bodies and farmer and food processing companies

IoT, Data Analytics and AI

Company: UjuziKilimo
Kenya

Application: IoT, Data Analytics and AI

Objectives:

- Data driven farming decisions across the value chain
- Increase in farm productivity
- Optimal use of inputs such as fertilizer, seeds and water usage
- Leverage of farm and environmental data and agricultural decision making

Key leverage:

- Remote data collection and farm monitoring
- Real time data analytics
- Farm advisory and recommendations
- Optimise input usage by 95% and productivity increase by 80%

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Glossary

2030 WRG	–	2030 Water Resources Group
AC	–	Application Centre
BVLOS	–	Beyond Visual Line of Sight
C4IR	–	Center for Fourth Industrial Revolution
CAR	–	Civil Aviation Requirements
CCI	–	Canopy Chlorophyll Index
CPP	–	Crop Protection Products
CSF	–	Critical Success Factors
DAN	–	Drone Acknowledgement Number
DAT		Disruptive Agricultural Technology
DGCA	–	Director General of Civil Aviation
DFI	–	Drones Federation of India
EVI	–	Enhanced Vegetation Index
EVLOS	–	Extended Visual Line of Sight
GARUD	–	Government Authorisation for Relief Using Drones
GDP	–	Gross Domestic Product
ICRISAT	–	International Crops Research Institute for the Semi-Arid Tropics
ISRO	–	Indian Space Research Organisation
IoT	–	Internet of Things
ML	–	Machine Learning
MoAFW	–	Ministry of Agriculture & Farmers Welfare
MoCA	–	Ministry of Civil Aviation
MPKV Rahuri	–	Mahatma Phule Krishi Vidyapeeth Rahuri
MSP	–	Multistakeholder Platform
MWRRA	–	Maharashtra Water Resources Regulatory Authrority
MWSIP	–	Maharashtra Water Sector Improvement Project
NDA	–	Nishith Desai Associates
NDVI	–	Normalized Difference Vegetation Index
NPNT	–	No Permission No Takeoff
NPSTA	–	National Programme for Use of Space Technology
OPA	–	Online Permission Artifacts
PoCRA	–	Project on Climate Resilient Agriculture
RPA	–	Remotely Piloted Aircraft
SMART	–	State of Maharashtra Agriculture Rural Transformation Program
SRSAC	–	State Remote Sensing
UAV	–	Unmanned Aerial Vehicles
UNTIL	–	United Nations Technology Innovations Lab
UTM	–	UAS Traffic Management Policy
VLOS	–	Visual Line of Sight
WRD	–	Water Resources Department
WSI	–	Water Stress Index

Front and Back cover pic credit: DMAC-PMU Ramthal; 2020 WRG

2030 Water Resources Group

Government of Maharashtra