United Nations Development Programme

PRECISION AGRICULTURE FOR SMALLHOLDER FARMERS

Precision Agriculture for Smallholder Farmers is a product of the UNDP Global Centre for Technology, Innovation and Sustainable Development, Singapore.

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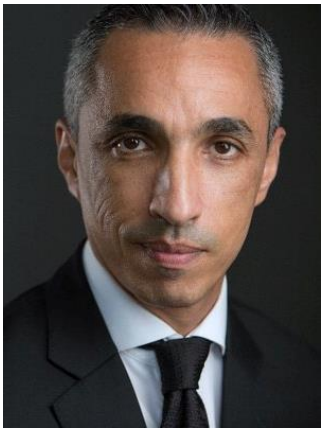
Foreword



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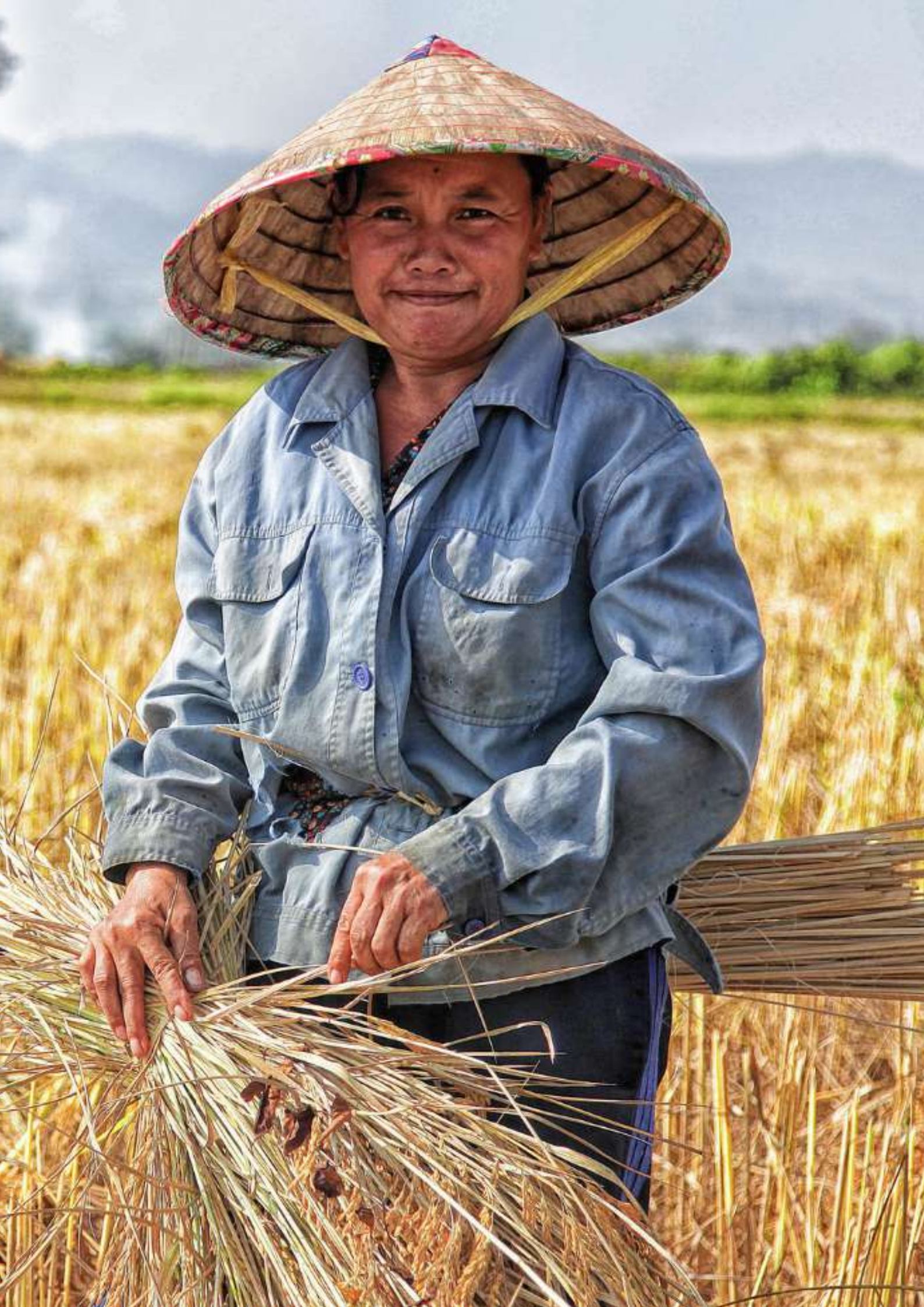
Global agri-food systems are under immense pressure. The world's population is estimated to increase to almost 10 billion people by 2050 and feeding it would require increasing current food production by up to 98 percent. Agriculture accounts for more than 70 percent of the global freshwater use, about half of which gets wasted. Globally, about a third of the food produced gets lost of wasted. Agriculture is a major contributor to the climate crisis and is also impacted by it—particularly in developing countries. Moreover, the COVID-19 pandemic has disproportionately affected the most vulnerable stakeholders, including smallholder farmers worldwide, and has put a spotlight on the several systemic issues in the sector.

Agriculture, however, is undergoing a 'Digital Revolution', with immense potential for improving the lives and livelihoods of farmers around the world. *Precision Agriculture for Smallholder Farmers* aims to contextualise and map the various innovations emerging in the area of digital farming. With a focus on smallholder farmers in developing countries, the report gives an overview of the technologies enabling digital and data-driven farming, highlights the key challenges preventing their large-scale adoption, and provides recommendations and important considerations for overcoming them.

Digitalisation is transforming all stages of agri-food supply chains, from production and processing to distribution and consumption. The use of data often transcends boundaries between these stages. Farm-level data has uses beyond the objectives of precision agriculture; it can be leveraged by supply-chain actors other than farmers such as input suppliers, credit and insurance providers, and retailers to improve their service offerings to farmers. This report focuses on the use of farm-level data to improve productivity and yields.

Agri-food systems are at the heart of the 2030 Agenda and impacting all 17 Sustainable Development Goals. Across the globe, UNDP is sharing climate-smart agricultural tools and practices, promoting livelihood diversification, new policies, and transformative changes in social traditions to empower the ones left behind. UNDP's Strategic Plan 2022-25 envisages digitalisation as an enabler for maximising development impact. We hope that this report contributes to the acceleration of efforts to create a new paradigm of agricultural production, based on resilient, equitable, healthy, and inclusive sustainable agri-food systems.



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List of Abbreviations

AEW	Agricultural extension workers
AI	Artificial intelligence
ARaaS	Agricultural robots-as-a-Service
ARVI	Atmospherically resistant vegetation index
AWD	Alternate wetting and drying
B2B2C	Business-to-business-to-consumer
B2C	Business-to-consumer
B2G	Business-to-government
CAVIS	Clouds, aerosols, vapours, ice, and snow
CGIAR	Consultative Group on International Agricultural Research
CSO	Civil society organisation
DEM	Digital elevation models
ESA	European space agency
ET	Evapotranspiration
FAO	Food and Agriculture Organization of the United Nations
GEO	Geosynchronous Equatorial Orbit
GPS	Global Positioning System
ICT	Information and communications technology
IoT	Internet of Things
ITU	International Telecommunications Union
IVR	Interactive voice response

LEO	Low Earth orbit
LMICs	Low- and middle-income countries
LPWAN	Low-power wide area network
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NBR	Normalised burn ratio
NDVI	Normalised difference vegetation index
NIR	Near infrared
NPK	Nitrogen, Phosphorus and Potassium
PxD	Precision Development
RGB	Red, Green and Blue
ROI	Return on investment
SDGs	Sustainable Development Goals
SMS	Short message service
SWIR	Short-wave infrared
TIRS	Thermal infrared sensor
UAV	Unmanned aerial vehicle
UNDP	United Nations Development Programme
USGS	United States Geological Survey
USSD	Unstructured supplementary service data
VRT	Variable rate technology

Executive Summary

In the coming decades, world agriculture will need to undergo a major transformation to meet the future demands of a growing population. By 2050, the food industry will have to face the daunting challenge of feeding about 10 billion people by almost doubling its food supply in a sustainable way.

Smallholder farmers in developing countries—who constitute about 90 percent of all farmers worldwide—will be a major part of the global food security equation. However, several challenges prevent them from turning farming into a viable and sustainable source of livelihood. Smallholder farmers suffer from low farm productivity and yields as well as lack of access to inputs, credit, and markets. They are also disproportionately vulnerable to shocks such as extreme weather events, now increasingly frequent due to climate change.

Precision agriculture is a farm management approach that uses data and technology to make farming simpler, more efficient, and more productive. Precision agriculture reduces the need for agricultural inputs like water, fertilisers, and pesticides, thereby reducing costs and the environmental footprint of agricultural production. The use of technology also cuts down the need for physical labour and improve productivity, ultimately enhancing the profitability of farming as a source of livelihood.

Digital technologies are making precision agriculture solutions increasingly affordable and accessible to even smallholder farmers in developing countries. These include mobile phones, remote sensing using satellites and unmanned aerial vehicles (UAVs), and sensors and the Internet of things (IoT)—all enabled by advances data processing

additional capabilities. Cost-effective and scalable mobile phone-based farming advisory services are already helping millions of farmers worldwide, overcoming the challenges with conventional agricultural extension. Through mobile phones, farmers can receive customised and localised advice on what, when, and how to grow, as well as alerts on weather, pests, and diseases.

Remote sensing using satellites is also supporting precision agriculture. This is made possible through the increasing availability of high-resolution imagery from satellites. Satellite imagery provides a snapshot of a large area of farmland in a single image. This imagery can be analysed—including through use of machine learning (ML) algorithms—for applications like nutrient status and crop health monitoring and yield estimation for individual farms.

Albeit less scalable than satellites, UAVs also offer remote sensing capabilities and high resolutions that satellite imaging, enabling additional applications like weed and pest detection. Based on this, variable rate maps can be generated specifying the amounts of inputs (e.g., fertilisers, pesticides, weedicides) required in different parts of the farm, thereby helping avoid their excessive application. In addition to remote sensing, UAVs can also be used for precise application of these inputs, substantially reducing the amount of physical labour required. While the technology remains unaffordable for individual farmers, contractors can leverage 'drone-as-a-service' business model to cater to a large number of farmers through farmer groups or cooperatives.

Various onsite sensors can also be used to collect accurate