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AGRICULTURAL INNOVATIONS AT THE TECHNOLOGICAL FRONTIER IN INDIA

Innovations in agriculture hold the key to unlocking sustainable, inclusive growth potential while securing employment opportunities for young people. In India, this has given rise to a new generation of entrepreneurs and startups that have increased agricultural productivity and producer income. Key developments in Indian agriculture have been in areas such as digital innovations for pre and post-harvest management, efficient energy sources, biotechnology and the 'uberization' of farm mechanization. These innovations have opened up new avenues of engagement with the sector and created job opportunities for technology developers, entrepreneurs and agribusiness specialists. India's success in launching these innovations in smallholder agriculture has potential for replication in other developing nations, including smallholder economies of Africa, through partnerships for cooperation and knowledge transfer.

Agriculture in India – a breeding ground for innovation

As the second most populous country in the world, India faces the dual challenges of ensuring food security and providing the enabling conditions for its people to secure a stable livelihood. Within these challenges are contained seeds of opportunity that have catalyzed innovative developments in the country's agricultural sector. The sector benefits from a large, dynamic workforce and from institutional capacity built through public spending during the Green Revolution that helped modernize the sector. However, during the last 15 years, the Gene revolution, as embedded in the fast spread of Bt cotton to 95 percent of cotton area, led by the private sector, has resulted in major gains both in terms of increased production of cotton, exports as well as incomes of cotton growers, including those of small and marginal farmers. The success of Bt cotton in India lies in the fact that cotton production increased from 14 million bales (of 170 kgs) between 2000-01 to 35 million bales in 2016-17 and yield increased from 278 kg per hectares to 568 kg per hectare during the same period. This enabled India to become the leading producer of cotton accounting for 26 percent of the global cotton production. India also emerged as a large exporter of cotton with exports rising from USD 0.9 billion in 2005-06 to a peak of USD 4.9 billion in 2011-12. It is estimated that the country gained approximately USD 55 billion during 2003-04 to 2014-15 as a result of this gene revolution compared to the business-as-usual scenario. Given these characteristics and developments, India is well-positioned to adapt cutting-edge innovations in agricultural technologies.

Information technology for better planning and management

Examples: mobile phone-delivered agricultural and market intelligence services, virtual agricultural marketing platforms, digital logistic platforms

Mobile phone usage is already widespread in much of the developing world. The existing proliferation of mobile technology therefore represents an opportunity to reach rural farmers who were previously beyond the reach of traditional service providers. Digital technologies can help **farmers make better management decisions** where monitoring systems and information dissemination infrastructure is weak or lacking. It can also be used to offer marketing and financial services. Such services can help farmers better **manage their risk** and access inputs and larger markets, resulting in better long-term planning, more stable and higher income and secondary job-creation through network effects.

Case study: mKRISHI@Fisheries

This is an easy to use application that provides fishermen with information about weather and water conditions at sea. Using this information, fishermen can reduce unnecessary trips and navigate more safely. A study by the Central Marine Fisheries Institute conducted in Maharashtra, India, found that fishermen could save up to 30% on fuel consumption using this application.

Advanced digital technologies for pre- and post-harvest management

Examples: sensor and mobile connectivity-based smart irrigation control, acquaculture monitoring and automation using on-farm diagnostic equipment, drones and satellite imagery; produce dehydration technology

Mobile phone technology can operate hand-in-hand with other forms of digital technology to **make precision agriculture** available to farmers in developing countries. These tools can not only help **optimize decision-making at the farm level**, but can also help farmers **tackle post-harvest losses**, which poses a significant challenge in India, and **better integrate and manage supply chains**. The automation of certain processes reduces costs for farmers and optimizes input use, while diagnostic and imaging tools offer farmers valuable real-time information about their crops. Processing technologies remove the perishability constraints under which farmers operate, potentially reducing price volatility in the local markets for produce.

Cutting edge digital technologies can also have market-wide impacts in developing **agricultural financial markets** in rural areas. Agricultural financial service providers in the private sector can identify geographical zones scoring high or low for different types of risk using tools such as remote sensing technology, machine learning and artificial intelligence. More accurate risk assessment increases transparency and can encourage private sector actors to extend crop insurance or agricultural credit to farmers whose risk level was previously too hard to determine and monitor.

Case study: CropIn Technology

The Indian startup CropIn Technology uses cloud and mobile technologies to collect and analyze data at the level of individual farms, clusters of farms, districts, states and the country. Different applications, including SmartFarm, SmartSales and mWarehouse, are assisting farmers, processors and traders in managing the entire value chain, from planting to harvesting and to the initial packaging, until the last mile of delivery.
In addition, the application SmartRisk offers a digital platform which helps micro finance, banking and non-banking financial institutions to identify and minimize risks associated with lending and insurance business using advanced data gathering and analysis tools.

Uberization of farm mechanization

Example: tractor-leasing services

Capital-poor farmers who farm on small plots of land (85% of holdings in India are of less then 2 ha) are generally unable to invest in mechanical equipment such as tractors. Startups, and now even tractor manufacturers, have found a way to service farmers who would like to mechanize but may lack the capital to do so through **virtual demand aggregation platforms** enabling farmers to **lease machinery**. This short-term leasing model driven by information technology has been coined 'uberization'. The obvious benefits of this innovation are cost cutting and **productivity gains** for farmers, but the community at large can also benefit from enhanced **employment opportunities** in rural areas. Youth in particular can be trained to operate and service the machines at the village level. Furthermore, this business model represents an investment opportunity for local entrepreneurs.

Case study: Custom Hiring Centres (CHCs) in India

As part of the Sub Mission on Agricultural Mechanization guidelines published in 2014, the Government of India introduced CHCs at the village level which rent out machinery, making mechanization accessible and affordable for farmers. The government provides subsidies to entrepreneurs willing to set up CHCs locally. Each CHC has a target to serve 10 hectares per day and 300 hectares in a season.

Efficient energy sources for smart and sustainable agriculture

Examples: LED-powered greenhouses and protected cultivation sites, hydroponic cultivation technology with artificial light, solar-powered irrigation and cold storage

Climate-smart agriculture reduces agriculture's carbon footprint and increases resilience to climate shocks. **LED lighting** has a proven energy efficiency compared to the high-pressure sodium lamps usually found in greenhouses. This technology can simultaneously **increase productivity** by speeding up growth rates while **saving on energy costs**. Furthermore, protected cultivation sites can reduce the need for pesticides and chemicals, leading to **better health outcomes** and **lowering variable input costs** for producers.

Case study: ecoZen

The Indian company ecoZen has designed a micro solar-powered cold storage system. The systems is targeted specifically at rural producers as it does not require grid electricity. The cooler is adaptable to local conditions across the world. According to ecoZen, the breakeven period is two years, and the product leads to an increase in profits of over 40%.

Solar panel technology holds enormous potential, especially in rural areas where access to electricity is irregular and diesel is the most common alternative. There are more than 7 million diesel powered irrigation pumps in India that can be replaced by solar powered pumps, leading to major savings in costs and also reducing pollution. Not only does solar infrastructure allow farmers to **save on energy costs** in the long-run, it can also provide an alternative source of income by pumping electricity back into the grid, which has the additional effect of leading to a more **stable electricity supply** at the local level and stable farmer incomes from solar panels as 'third crop'.

Case study: BioAg Alliance

BioAg Alliance is a strategic partnership between the biotech companies Monsanto and Novozymes with the goal of developing microbial technology solutions to help boost agricultural productivity and support natural resource management. Microbes are produced by fermentation. The resulting products can be applied to seeds before planting, in-furrow or sprayed on crops. These protect the crops and supply nutrients. The market for microbials was estimated at USD 1.8 billion in 2014.

Innovations in crop nutrition for healthy soils and water resources

Examples: Mycorrhiza, algae-based bio stimulants, Neem oil spray-on urea, microbial crop protection and nutrient technology, pheromone insect traps

Sustainable, climate-resilient agriculture requires solutions which **reduce farmers' reliance** on agricultural chemicals while maintaining or even **increasing yield levels**. Advances in our understanding of plant nutrition have led to the development of innovative alternatives, including fungal, microbial and pheromone-based products.

These have the potential to provide such a solution, with positive implications for soil quality and reducing water contamination. Technologies that decrease the need for fertilizer include fungal microorganisms, which increase the efficiency of a host crop's nutrient absorption, and fertilizer coating, which slows the release of nitrogen. Eco-friendly pest control solutions are being developed, reducing the need for pesticides while improving yields, encouraging organic farming and yielding chemical-free consumer products.

Biotechnology

Examples: Bt cotton; drought tolerant maize; Vitamin A, iron and zinc enriched crops; micronutrient fortified edible oils and milk

The journey from Green to Gene Revolution in agriculture has helped several countries decrease their reliance on food aid and imports, and enabled their **transition into food-secure countries** with **exportable food surpluses.** One such development has been in the field of biofortification, which has seen the release of 100 varieties of 10 crops in 30 countries. Staple crops, fortified with essential vitamins and minerals, can help **combat widespread malnutrition**.

Case study: HarvestPlus

As part of the global HarvestPlus program, iron rich pearl millet and zinc rich wheat are available in India while other crops are undergoing testing. The enriched millet can provide 80% of daily iron needs while the wheat can meet 50% of zinc needs. The biofortified staple crops can benefit in particular Indian children; 70% of under-five year olds are estimated to be iron deficient and 48% zinc deficient.

Seed technology can be further harnessed to address specific challenges, yielding varieties that are **more productive, more resilient to weather shocks and pest attacks**, or that **use inputs more efficiently**. Cultivating improved seed varieties developed for the international export market also gives farmers the opportunity to **diversify their income source**s by tapping into the large international demand for cash crops. This translates into risk-reduction and higher incomes for farmers.

The Way Forward

The innovations described in this policy brief are drawn from an extensive stocktaking exercise of the types of innovations that have emerged globally and in India, and have the potential to benefit the agricultural sector, farmers and consumers in India and other developing countries, especially smallholder dominated economies of Africa. Businesses and startups play an important role in the ongoing developments in this area and many innovations are still at an early stage of implementation. **More comprehensive impact pathway research, quantifying benefits and costs, and implementation research** is called for to accelerate design and facilitate access to innovations by the masses of Indian farmers while **ensuring equity and sustainability of resource use.**

In addition, **enabling policies, institutions and partnerships** hold the key to making innovations work and catalyzing growth and development. Some the key next steps in ensuring that the ongoing efforts gain more pace and deliver greater benefits to the farmers and other stakeholders in the value chain include:

Investing in Innovations

The political will to mobilize public resources is the key to enabling the conditions for innovations to develop and be scaled up. Capacity-building in sectors relating to agriculture can help create an ecosystem in which farmers can benefit from new technologies. Government programs targeting youth specifically are also crucial to promote long-term, sustainable growth in the agricultural sector. Special incentive programs can help attract and retain entrepreneurial talent in agriculture.

Accelerating the commercialization of technologies

Lack of access to financing and capital, and lack of skilled resources to service and update technology represent significant barriers to the commercialization and widespread adoption of technological innovations. Investments in monitoring and evaluation systems are needed to identify further barriers to adoption within specific geographies and value chains, and better understand and address them.

Setting up regional and international exchange and knowledge-sharing programs

To keep up with the rapid rate of technological development, cross-stakeholder platforms need to be set up to encourage knowledge-transfer. At the regional level, links between governments, the private sector, the technology sector and farmers can lead to fruitful collaboration. At the international level, innovators from one country can work with local entrepreneurs in another to adapt successful innovations to different local contexts. High-level triangular partnerships, e.g. India-Africa-Germany, should also be promoted.

Recommended policy measures:

- Prioritize public investment into agricultural infrastructure, irrigation and advisory services projects
- Set up flagship government programs such as Digital India and Startup India to promote technology-led entrepreneurship
- Collaborate with the agribusiness sector on pilot programs and R&D initiatives
- Organize international or rural-urban youth exchange programs
- Establish a global agricultural startup platform

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IMPRINT
Center for Development Research (ZEF)
Walter-Flex-Str. 3 | 53113 Bonn | Germany
E-Mail: presse.zef@uni-bonn.de
Phone: +49-(0)228 - 73 18 46
Brief prepared by: Evelyn Baraké

ICRIER

zef
Center for Development Research
University of Bonn