

Investigation of Information and Communication Technology in Indian Agricultural Research

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Abstract: In order to make strategic decisions about agricultural production and protection research, computers are being utilised for mechanisation, automation, and the development of decision support systems, expert systems, GIS, and remote sensing. Geographic information systems and remote sensing have recently played a significant and vital role in agricultural research, particularly in the areas of yield prediction, soil suitability for a given crop, integrated pest management, water management, site-specific resource allocation of agricultural inputs, etc. Over the last 60 years, India has made remarkable strides in agriculture. Currently, there are many issues that need to be prioritised in order to advance agriculture and turn India into a developed country. In the present millennium, there are issues with both a large population and a lack of resources and land. As a result, Indian agricultural research faces difficulties in feeding the country's growing population. It is now well acknowledged that information and communication technology (ICT) is a very potent enabling instrument for service delivery in both the public and commercial sectors. ICT has the ability to both spread and alter agricultural research knowledge and information. Since science and technology are accessible everywhere, it is important to recognise that knowledge and information are equally accessible everywhere. This creates opportunities for global collaboration in agricultural research and development.

Keywords: India, research, agriculture, ICT, and information communication technology

I. Introduction

As of November 11, 2013, at 00.05 hours, there were 1.244 billion people living in India and 7.234 billion worldwide (www.indiastat.com). In the 2011 Census India, the country's total population was 1,21,05,69,573 (100%), with 83,34,63,448 (68.8%) in rural areas and 37,71,06,125 (31.2%) in urban areas. India had the second-largest population in the world. In 2011, there were 11,86,92,640 cultivators in India (24.6% of the country's total population), with 11,49,68,498 in rural areas and 37,24,142 in urban areas. There were 14,43,29,833 agricultural labourers overall, 13,69,94,451 in rural areas (30% of the total population), and 73,35,382 in urban areas. In 2010–11, the area used for agriculture was 159.18 million hectares. According to the 2010–11 Agricultural Census, each individual had an average of 0.80 hectares of land. India accounts for 3.71% of global agricultural imports (FAO Statistics, 2011). ICAR has 99 research institutes in India that do agricultural science research. Foodgrain production rose from 50.83 million tonnes in 1950–51 to 255.36 million tonnes in 2012–13. Land, water, and resource scarcity, as well as a very large population, are issues that must be addressed concurrently in the current millennium. The Indian agricultural scientific community has several obstacles in providing food security to the growing population. One of the key economic sectors in India is still agriculture. It continues to be the main source of income for 70% of the population and accounts for 60% of employment. Therefore, agricultural technological advancement is essential to the nation's overall economic growth. An estimated 328.8 million hectares make up India's whole land area. Of the approximately 180 m.ha. gross cropped area, 35 m.ha. are double cropped. The most significant crop is rice, which is followed by wheat, pulses, oilseeds, sorghum, and maize. The two main commercial crops are sugarcane and cotton.

II. The Present Agricultural Research Systems of India

With more scientists than any other emerging nation outside of China, India has one of the biggest agricultural research systems in the world. About 30,000 scientists and over 100,000 support personnel are actively involved in agriculture-related research within the research system. While India seems to have a highly outstanding number of experts working on agricultural research, this number is not as high as in many wealthy nations. Through its extensive network of 30,000 scientists employed in government institutes, the Indian National Agricultural Research System (NARS) serves the demands of agricultural research and education. The green, white, yellow, and blue revolutions are examples of scientific advancements in agriculture. The information technology revolution of today has become crucial for working scientists and research managers. The ICAR at the federal level and the Agricultural Universities at the state level make up the two primary streams of the current agricultural research system. Currently, 45 agricultural universities exist, including the Central University in the Northeast.

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Additionally, a number of other organisations, including General Universities, Scientific Organisations, and other

Ministries/Departments within the Center, as well as Private or Voluntary Organisations, either directly or indirectly engage in agricultural research.

III. National Agricultural Research System

1. The system of ICAR
2. The System of Agricultural Universities
3. Additional Organisations
4. Connections Between the Subsystems
5. International Collaboration

IV. Application of Computer in Agriculture Research

Simple data computation, data storage, simulation models, expert systems, decision support systems, research management systems, trend forecasting, virtual farms, information flow, sharing data and knowledge, etc. are just a few of the many aspects of computer application in agriculture research. In order for the use of computer technology and information technology (IT) in agricultural research to produce beneficial outcomes, it is necessary to modify our traditional working techniques and create new systems. The same computers were used in the next generation for mechanisation, automation, and the development of decision support systems for making strategic choices about agricultural production and protection studies. Geographic information systems and remote sensing have recently played a significant and vital role in agricultural research, particularly in the areas of yield prediction, soil compatibility for a certain crop, site-specific resource allocation of agricultural inputs, etc. The Indian computer software sector has been "a source of dynamism and technological innovation, providing demonstration effects for other industries in terms of export orientation, strategic alliances, and foreign investment." It has been enhancing India's reputation outside for its technical and entrepreneurial prowess. India, which has recently gained recognition for its proficiency in computer software creation, is quickly becoming as a global leader in this area as well. Although the number of computers in the globe changes daily, it is estimated to be around 850 million. 57 million PCs, or 3.56% of the global total, are in use in India. Many individuals in the developed world are surprised by how many people in developing nations have access to mobile phones. At the beginning of 2012, 137 million Indians were using the internet every week, according to the IAMAI (Internet and Mobile Association of India). Even while it is over double the UK's entire population, it still only makes up 8.2% of India's 1.244 billion people. Only 24 million individuals in rural regions have access to the internet, whereas 83% of internet users are men who live in cities. The Indian government has been active in initiatives to provide inexpensive computers to underprivileged groups and has declared that more internet access will have a significant positive impact on research and education in the nation.

WORLD INTERNET USAGE AND POPULATION STATISTICS June 30, 2012						
World Regions	Population (2012 Est.)	Internet Users Dec. 31, 2000	Internet Users Latest Data	Penetration (% Population)	Growth 2000-2012	Users % of Table
<u>Africa</u>	1,073,380,925	4,514,400	167,335,676	15.6 %	3,606.7 %	7.0 %
<u>Asia</u>	3,922,066,987	114,304,000	1,076,681,059	27.5 %	841.9 %	44.8 %
<u>Europe</u>	820,918,446	105,096,093	518,512,109	63.2 %	393.4 %	21.5 %
<u>Middle East</u>	223,608,203	3,284,800	90,000,455	40.2 %	2,639.9 %	3.7 %
<u>North America</u>	348,280,154	108,096,800	273,785,413	78.6 %	153.3 %	11.4 %
<u>Latin America / Caribbean</u>	593,688,638	18,068,919	254,915,745	42.9 %	1,310.8 %	10.6 %
<u>Oceania / Australia</u>	35,903,569	7,620,480	24,287,919	67.6 %	218.7 %	1.0 %
<u>WORLD TOTAL</u>	7,017,846,922	360,985,492	2,405,518,376	34.3 %	566.4 %	100.0 %

Source: www.internetworldstats.com

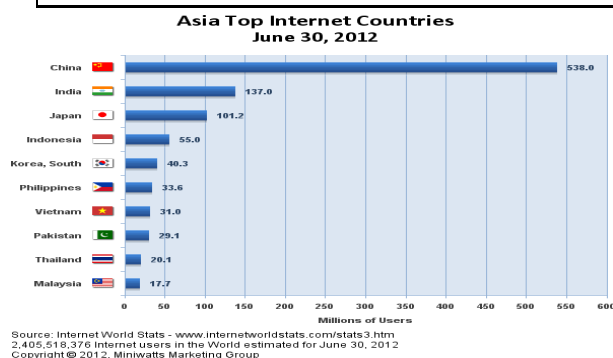


Figure 1: IT-based Agro-advisory system

Source: <http://www.iiit.ac.in/files/iiit/eSaguShyam.jpg>

V. Present Status of ICT in Indian Agriculture

Funded by the World Bank under the National Agricultural Research Project (NARP) and later the National

Agricultural Technology Project (NATP), the ARIS "Agricultural Research Information System" program produced awareness, access to basic computer facilities, Internet connectivity, email, database development, application software, and HRD in computer applications. It is now time to move toward more complex real-time, system-wide applications for managing and conducting agricultural research through a computerised system. This is required to address the current challenges of attaining higher growth rates along with effective and timely delivery systems. Thus, ICAR has created infrastructure for database building and efficient information access at most National Agricultural Research System (NARS) institutes via its ARIS initiative. The system has greatly benefited from ARIS's better research, planning, distribution of research results, information sharing mechanism, feedback mechanism, and assistance in introducing an element of transparency in information flow. By addressing their information demands, information communication technology (ICT) has enabled much-needed community growth and empowerment. Additionally, ICT plays a significant role in helping researchers complete work more quickly, effectively, and efficiently. The agricultural industry in India has just as much potential for growth as any other. ICAR has started a number of ICT initiatives for the nation's agricultural industry. ERNET, NICNET, NATP, ARIS, ATIC, NME-ICT, NKN, AgRIS NET, Agri-Daksh of IASRI, NISAGENET of ICAR, MSSRF, Chennai, econnectivity of 200 Krishi Vigyan Kendras nationwide, Agricultural Research Portal, Centralised and Secure Data Center, National Agricultural Bioinformatics Grid, Digital Repositories of Research Information, e-Learning courseware for undergraduate and graduate programs in agriculture, epublishing and Open Access of research journals, MIS for e-Governance, and Inflibnet are some of the major ICT initiatives. Approximately 2,000 foreign publications are available in more than 120 libraries under the National Agricultural Research System (NARS) via the Consortium for e-Resources in Agriculture (CeRA), which was founded at Indian Agricultural. Up to October 2010, over two million people visited the CeRA website, and over 1.5 million full-text papers were downloaded. In addition to facilitating data sharing and the creation of web analytics useful for All India Coordinated Research Projects and other Network Projects of the NARS system, which enables farmers to send queries to agricultural experts in their local languages through SMS to mobile devices and receive personalised advice or pertinent information in the local language by Tata Consultancy Services Ltd. (2009), a high-end statistical package SAS would allow the researchers in NARS to undertake probing, in-depth, appropriate, and intractable analysis of data generated in advanced research areas. IIT, Kanpur, and ICRISAT have created Agropedia, a multilingual agricultural knowledge library comprising global meta models and Indian localised information, for a range of users under the NAIP of ICAR. Supercomputing facilities for doing agricultural bioinformatics research are being constructed as part of an ambitious project called "Establishment of National Agricultural Bioinformatics Grid (NABG)." The computing foundation provided by this national center will help the nation's biotechnology research. The project's top goal is to develop databases, data warehouses, software and tools, algorithms, genome browsers, and advanced computing capabilities in the area of agricultural bioinformatics using a methodical and integrated approach. The agriculture industry needs sufficient, trustworthy, and timely information and analysis on a number of business-related topics, including significant domestic and worldwide markets, supply and demand patterns, scientific forecasts, crop and weather data, and how these factors affect the industry.

Governments, nongovernmental organisations, businesses, and some foreign projects are the main sources of ICT initiatives in India's agricultural industry. While some programs address the problem of agricultural information accessibility, others provide rural residents comprehensive services. Some of the first national level initiatives include the Ministry of Agriculture and Co-operation, the Government of India, several State Agriculture Departments, MSAMB, APEDA, and AGMARKNET, an initiative by NIC (2000) to provide market price information across the nation's agricultural markets; the Ministry of Agriculture, GOI (2004); e-Sagu, a cost-effective ICT-based agricultural information dissemination system for expert agricultural knowledge to the farming community by IIT, Hyderabad (2004); and Kisan Soochna Kendra by IIT, Roorkee (2005). Tenet Group of IIT Chennai created nLogue, a wireless rural networking system, to supply village kiosks and link each village in a district via terrestrial wireless. Agriwatch.com, a portal for farmers, traders, processors of agricultural outputs, suppliers of agricultural inputs, etc. by Indian Agribusiness Systems Pvt. Ltd. (2001), Drishtee.com, a rural supply chain and distribution network, and iKisan.com, an agri portal for addressing the information, knowledge, and business requirements of various players in the agri arena, namely Farmers, Trade channel partners, and Agri Input/Output companies by Nagaarjuna group of private companies, are a few examples of ICT-based agribusiness initiatives. Using information on plant characteristics, weather, and agricultural inputs, ICT-driven techniques have been created to predict crop output ahead of harvest. These methods make it possible to predict crop production at the state and district agroclimatic zone levels one to two months prior to crop harvest. Techniques for predicting important agricultural diseases and pests have been developed. ICTs have been used to provide expert knowledge and power to even tiny farmers in the most distant regions of the nation in real time, helping the rural people in certain areas. The information might even be tailored to support or assist the particular farmer in making decisions about crop and variety selection, need-based agricultural methods, and markets for product sales. There are several agricultural ICT programs that target different aims and use diverse strategies to achieve national objectives.

VI. Sustainable Development

The need for sustainable agricultural growth has created new obstacles for the advancement of farm technology as well as for its rapid distribution and integration into farmers' fields. Along with soil, seed, water, fertiliser, pesticides, farm tools, etc., information and knowledge are currently among the most important inputs to agriculture. In order to increase agricultural production and farm profitability while safeguarding delicate natural resources, it is now essential to have access to information and expertise regarding weather forecasts, agro-advisories, agricultural pricing, inputs, proper farm practices, trustworthy research suggestions, etc. The current method of information and knowledge exchange between research managers, research personnel, and extension equipment is unable to provide the intended outcomes. As a result, it is now essential to use contemporary information communication technology to effectively and efficiently handle the information resources associated with agricultural operations. Therefore, in order to meet the demands of modern planners and double the growth rate of the agricultural sector to reach the targeted 4% annually, the traditional agricultural research education-extension system must evolve into a more adaptable, responsive, and proactive Agricultural Knowledge Management System. It is widely acknowledged that the public research-education-extension system plays a significant role in achieving food production self-reliance. However, the country's many challenges cannot be addressed by the old public research education-extension system in this changing era. Global marketing, agribusiness, quality-conscious customers, and WTO difficulties are only a few of the increasing challenges that the current public research-education-extension system must deal with. It is also hampered by a lack of resources, wide distribution, and a variety of tasks. The development of an all-encompassing agricultural research education-extension system that is shared by all stakeholders is necessary. National planners, research managers, scientists, educators, students, farmers, cooperatives, agricultural consultants, farmers organisations, unemployed agricultural graduates, nongovernmental organisations, Krishi Vigyan Kendras (KVKs), state extension agencies, agribusiness companies, input dealers, newspapers, agricultural magazines, private television channels, private sector banks, market information systems, weather forecasting agencies, and more are examples of these stakeholders.

The output and productivity of key grains in the guaranteed irrigated regions were abruptly increased by the Green Revolution. One of the most important inputs in the transfer of agricultural technology is the prompt distribution of technological information from the Agricultural Research System to farmers in the field and the reporting of farmers' comments to the research system. For the last fifty years, traditional methods have been the primary means of providing information and communication assistance. The Department of Agriculture's extension staff physically distributed the technical messages to farmers. The bulk of farmers, who are dispersed across the whole nation, have not been reached by this strategy. This problem is made more difficult by the variety of agro-ecological circumstances. The demands of farmers are becoming more varied, and extension workers at the local level lack the expertise needed to meet those needs. By using the potential of Internet-based technology to satisfy the farmers' location-specific information demands, a solution to this problem may now be found. Networks for communication and information are growing at a very rapid pace. Nearly every district in the nation now has internet access, and it is even reaching the block and village levels. There are many pilot initiatives under progress to link rural communities to cyberspace. The Internet and intranet have expanded greatly as a result of the convergence of computers and communication technologies. Village Information Concept Kiosks are rapidly expanding into villages, blocks, and mandals, giving Indian farmers digital access to crucial information that can be found online. Numerous cyber-experiments are being conducted in rural India, and they have clearly shown the potential of information technology and the Internet. Large-scale replication of cyber extension programs is now possible due to farmers' overwhelming reaction and readiness to adopt such systems. Creating relevant digital material via vertical integration and horizontal sharing is a problem for the nation's agricultural research and education sector. India is a big country with natural physical, biological, and cultural variety, which makes communication and information sharing difficult. This also applies to agriculture. The 143 Mha of net land under cultivation in India is split into around 115 M holdings, of which 56.7% are less than 1 ha, known as Marginal Farms, and 20% are in the 1-2 ha range, known as Small Farms. Thus, up to 3/4 of India's agricultural population consists of farmers with small and marginal holdings. They often lack capital and managerial skills, have low literacy rates, and are impoverished. Although it is still very difficult, spreading knowledge to this segment of the agricultural community is crucial for development. To meet these time constraints, information is essential. ICT makes it possible to quickly access information on a worldwide scale, which paves the path for addressing future difficulties in Indian agriculture. India is now a prominent agricultural country on a regional and global scale because to scientific advancements in the area of agriculture, including the green, white, yellow, and blue revolutions. Additionally, India is quickly becoming a global leader in information and communication technology and is renowned for its proficiency in computer software creation. As a result, India has all the components and labour needed to be successful in using computers and information technology for agricultural research. In order to support the expansion of the agricultural population and the nation as a whole, a computer-based National Agricultural Research Knowledge Management System is being adopted on a much bigger scale.

VII. National agriculture research data-center with super computing facilities and secured access through intranet

Modern Information and Communication Technology (ICT) facilities that are consistently maintained around-the-clock are essential for real-time computer applications in agricultural research. Over the last ten years of experimenting with computer applications in agriculture, it has been noted how challenging it is for individual institutions under NARS to maintain such facilities. Due to the ever-growing and technologically complex security risks, including as computer viruses, spam, phishing attacks, cybercrimes, and more, maintaining email servers, web servers, and local area networks (LANs) has become a major issue for the majority of the organisations under NARS. Due to the several-fold pay disparity between public research organisations and commercial ICT organisations, NARS is unable to attract and retain the highly qualified personnel needed to manage ICT systems. Creating integrated, well managed ICT facilities that are safely available to all institutions under NARS is thus the optimal course of action. Strategically, logistically, technologically, and financially, the ideal choice would be a National Agriculture Research Data-Center with supercomputing capabilities that can provide NARS members protected access over a secure intranet. In the very competitive field of ICT, NARS with a core expertise in agricultural research, education, and extension does not need to diversify too much. To serve as a system analyst, however, a core group of professionals with experience in both ICT and agricultural research is required. These professionals must be able to comprehend and define NARS's computer application requirements, communicate with highly qualified ICT professionals from the industry, guarantee proper computerised system implementation, and monitor and certify the computerised systems for long-term use in agricultural research. As we go into an age of intelligent organization, organisations' explicit and tacit knowledge is a priceless asset that should be digitally recorded so that it may be shared and enhanced without repetition for particular service goals. For generations to come, this digital knowledge must be safely and securely maintained in databases, expert systems, decision support systems, management information systems, and other applications. As a result, safe storage solutions are essential for every business. Such facilities are available to the agricultural research industry via the National Data Center. Digital storage, messaging servers, web servers, intranet application servers, database/data warehousing servers, and servers for various applications, such as financial management systems, research management systems, personnel management systems, knowledge dissemination and sharing systems, remote collaboration systems, weather forecasting and agro-advisory systems, high-end super computing facilities, such as for genomic research, can all be housed in the National Data-center.



Figure 2: Expert system on Agriculture Source: www.icar.org.in

VIII. Databases, data warehouses, commodity/crop portals, intercrop portals, expert systems, simulation models, and web services are examples of digital content.

Databases, data warehouses, commodity/crop portals, intercrop portals, expert systems, simulation models, and web services are examples of digital content. In order to create an organizational knowledge base and make pertinent information easily accessible to stakeholders, digitization of traditionally existent material has become more important. To fully use the potential of IT in agriculture, content in the form of webpages, databases, data warehouses, expert systems, application software, intranet and work flow applications, training modules, extension modules, web-based services, etc. is now essential. In accordance with policy, content owners may be encouraged to produce and distribute these materials.

IX. Agriculture Expert System

A particular kind of information system known as an expert system uses computer software to do tasks that are typically performed by experts. The decision-maker receives recommendations on the best course of action for a

certain issue scenario from the computer, which has been programmed to replicate the mental processes of experts. It is hoped that by creating computers, or information systems, humans would be able to think, learn, and act like experts. Expert systems enable users to impart experts' knowledge without the need for their physical presence. In any sector, but particularly in agriculture, where specialists are hard to come by, costly, or unavailable, expert systems are helpful. Since it includes information gathered from published literature and an expert in the field, the knowledge base is the fundamental part of any expert system. Knowledge gathering, knowledge representation, knowledge programming, and knowledge refining are the steps involved in creating any knowledge base. One artificial intelligence method in the field of agricultural information is agricultural expert systems, which are crucial to the transition from traditional to contemporary integrated agriculture. Data, knowledge representation, multi-media, internet, and integration approaches are among its fundamental methods. The Agriculture Expert System, or Agri-Daksha, was created by IASRI in New Delhi.

X. Geographic Positioning System, Geographic Information System, and Remote Sensing

The practice of obtaining data about an item at a distance without actually touching it is known as remote sensing (RS). The photographic picture of an item captured by a camera is the most popular remote sensing technique that most people think of. The capacity to capture data in both visible and invisible portions of the electromagnetic spectrum—such as ultraviolet, thermal infrared, reflected infrared, microwave, etc.—is a special feature of remote sensing systems. As a result, certain phenomena that are invisible to the human sight may be noticed using remote sensing methods. For example, trees damaged by disease or insect attacks can be identified by remote sensing techniques far in advance of being seen by human eyes. A geographic information system (GIS) is a computer-based information system that can gather geographical data from several sources, transform it into forms that are usable, store it, retrieve it, and modify it for analysis. GIS is now a multibillion-dollar sector that is a fundamental component of the information infrastructure used by academic institutions, governmental organizations, and commercial businesses. Thematic mapping, managing geographical inquiries, and supporting decision-making are the main uses of operational GIS. The use of remote sensing data has gained traction in India's agricultural and crop studies fields, particularly crop production forecasting, which includes crop inventory and yield forecast models, drought assessment, soil mapping and degradation, command area monitoring, flood damage assessment, land suitability mapping, insect pest infestation forecasting, and the widespread availability of satellite signals that enable private use of Geographical Positioning System (GPS). Agriculture researchers are using GIS technology more and more to build resource databases and develop suitable strategies and solutions for the sustainable development of agricultural resources. Due to advancements in space-borne remote sensing satellites' spatial, spectral, temporal, and radiometric resolutions, the use of remote sensing and GIS approaches in agricultural resource management is expanding quickly. Better integrating GIS with other software for statistical analysis, operations research, and artificial intelligence (AI) tools is a trend in the development of GIS analytical functions. Geographical information systems will probably grow easier to utilize in the future. Single-user systems are evolving into more open, multi-user systems with the growth of web-based GIS.

XI. Precision Agriculture

In order to reorganize the whole agricultural system in the direction of low-input, high-efficiency, sustainable agriculture, precision agriculture is envisaged using a system approach. The Global Positioning System (GPS), Geographic Information System (GIS), miniaturized computer components, automatic control, in-field and remote sensing, mobile computing, advanced information processing, and telecommunications are just a few of the technologies that have emerged and converged to support this new approach. The Maharashtra government has been successfully implementing an integrated pest management system for soybean crops for the last three years. This system employs ICT, GPS, and GIS to communicate data and control pests throughout the whole state. Dr. PDKV, Akola, has been using ICT to provide farmers in Maharashtra state's Vidarbha area with expert SMS messages on precision agriculture. More thorough data on production variability across time and place may now be gathered by agricultural research. Precision and sustainable agriculture now aim to address such variability on a fine-scale.

XII. Decision Support Systems

Decision support systems (DSSs) are computer programs that assist users in analyzing complicated data and making choices. Decision support systems are information systems designed to assist humans in solving problems and, to some extent, making decisions. DSS is made up of a number of individuals, processes, databases, and software. The main piece of technology in these systems is the computer. Both active and passive modes of operation are possible for decision support systems. While active systems provide guidance in certain circumstances, such as notifying technical staff when a parameter being monitored beyond its specified threshold value, passive systems are mostly used for reference by decision makers, specialists, or agricultural supervisors.

XIII. Conclusion

ICT applications and computer use are now widespread in all spheres of life. The usage of this new technology has helped corporations, banks, private businesses, and government-to-citizen applications. The ICT revolution also benefits the field of agricultural research and development. The use of ICT in agricultural research has also benefitted NARS. In order to meet the various demands of NARS, it is imperative that we go to the next higher level of computer applications by implementing countrywide integrated information systems. We must create our own guidelines for data exchange and digitalization in the field of agricultural research. Mega information systems at the national level and online services that are available from anywhere in the nation and the globe are urgently needed. Achieving future objectives would be aided by the synergy of integration, consolidation, and exchange of agricultural research data. In order to define priorities, develop strategies, monitor, and accomplish national objectives, a research planner or manager should be able to extract full information from the final National Agricultural Research Knowledge Management System. To carry out research mandates as effectively and efficiently as possible, a research scientist should have access to all information sources. By engaging with the system in the most user-friendly way possible and in their own or understandable language, a farmer sitting in a distant hamlet across the nation should be able to acquire the finest answers to his agricultural difficulties.

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