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Role of the National Innovation Systems in Agriculture Development of India: Policy and Practices

Abstract

Dr. Vikas Kumar[1]

This paper contends the National Innovation System (NIS) approach in agriculture in India. It also attempts to scrutinize the linkages between agricultural innovation and Research development that have evolved. The implementation of strategies enabled by institutional and organizational frameworks has contributed to enhancing agriculture production. Technological change and IPR still have been hostilely debated issues in India, yet agriculture activities are perused with agriculture innovation. Thus, the paper attempts to explore the technological transfer and its appropriation in a local milieu where varieties of patterns are followed by agricultural activities. By implication, it presents a case for a theoretical extension of understanding agriculture innovation in the line of NIS. Furthermore, the paper substantiates the growth in terms of research and development and Intellectual Property Rights (IPR) in the country's spatial pattern of agricultural development.

Keywords: National Innovation System, Agriculture Innovation, Intellectual Property Rights, Research and Development, Crop production,

JEL Classifications: O13; O34; Q16

[1] Assistant Professor, Indian Institute of Information Technology Vadodara – International Campus Diu.

1. Introduction

Science, technology, and innovation are major drivers for the world's economic development strategies. In this view, since the last few decades, there has been debate on innovation and finding out the best approach for science and technology (S&T) in agriculture sectors. Though, various changes occurred in terms of institutional, technological, and policy levels in Indian agriculture. The National Innovation System has a well-developed network from production to consumers. In the context of India, the National Agriculture Research System (NARS) is the largest public research system in the world, but its result has not been shown as it is intended or desired even though a large population depends on agricultural activities. Thus, solving the problem would require further technological interventions such as hybrid seeds, and irrigation facilities (i.e. drip and sprinkler irrigation systems) in the sector.

In this regard, knowledge plays a crucial role in agricultural innovation, which finds its meaning in a particular socio-economic context. Though innovation does not determine the diffusion of technology, it depends on the farmer's concern with various stakeholders. Over the last decade, the approach of agriculture has changed and many researchers stated that intervention of new technology in agriculture benefited only big farmers and that the process of development is embodied in the green revolution. Some scholars believe that in Indian agriculture, the mode of production has become capitalistic.

However, instead of insistence on the choice between either-or postulates, this paper is intended to detour through a critical examination of these formulations with the help of agriculture innovation and in what ways R&D and IPR enhance agriculture production through the use of scientific knowledge in the light of Indian experience and the extent of its length and depth. Therefore, this paper aims to:

1. Review the concept of an innovation system.
2. Appraise the application to agriculture and its relevance; and
3. Analyse the IPR implications on Agricultural Research and Development activities in India.

Based on the objectives of the paper, it has been categorized into six sections including an introduction. The second section discusses the evaluation of innovation and change, it also defines the concept of Innovation. The third section covers the concept of innovation systems in terms of agriculture. Section four elaborates on the role of R&D in accelerating the growth of agricultural innovation, and section five gives relevance to the IPR perspective in terms of India's experience. In this regard, section six concludes with the impact of them on agricultural production.

2. Evolution and changes in views of Innovation

The notions of innovation and their approach have changed over time. Many scholars (Kline and Rosenberg, 1986; Rip, 1995; Roling, 1996) have refuted a widespread presupposition about the linear model of innovation postulated as its development by scientists using extension and education, of late put into practice by farmers and the public in general. Also, it argues that ideas are generated from practical experience at the ground level. Therefore, scientific knowledge is limited. In this sense, innovations are based on the interaction of different actors. Leeuwis, (2004) talked about the different aspects of the ideas that are shown in Table 1, further explained.

Table 1: Different Approaches of Innovation

Aspect of innovation	A linear model of innovation (dominant 1950-1980)	Later modes of thinking (dominant from 1990 onwards)
Origin	Science and research	Building blocks come from science, practice, and intermediaries
Nature	New technical device	New successful combination of technological devices, modes of thinking, and social organization
Social conditions for application	Are 'outside' the innovation	are an integral component of the innovation
Key processes	R&D, adoption	Interactive Design, co-evolution, learning
Adoption	is an individual process	is a collective process within nested networks of interdependent stakeholders
Steering	Change can be engineered, predicted, and planned rationally	change is an unpredictable, messy, and emergent process
Role of science	Designing innovations	Delivering inventions that may be turned into innovations; responding to questions that emerge in the innovation process.
Diffusion	Happens after the innovation is ready	Starts already during design, while scaling out often includes the contextual re-design

Source: Leeuwis (2004)

It is not only the changing scenario of innovation but also the importance of innovation. This leads to the new concept that innovation is not only new technological arrangements but also socio-economic arrangements (Van Schoubroeck, 1999). It means that the various actors involved in the innovation process manifest in social dilemmas and crisscrossing relations and claims. This determines the coordination and interdependencies among people.

Thus, it defines innovation as new phenomena which consist of people, technical devices, and nature. In this regard, the innovation process also changed in the last decade. Nowadays, innovation processes are looked at from an evolutionary perspective. Essentially, it is described in terms of a variety of innovations and innovation processes competing in a dynamic selection environment in which only 'best-fitting will survive (Bijker, et.al. 2001; Rotmans, 2001).

3. Innovation System: A Theoretical Background

During the period of the mid-1980s, the approach of the innovation system emerged which is known as the Schumepeterain perspective, and later, Lundvall provided a more comprehensive description of innovation (Speilman, 2005). However, many scholars (Freeman, 1987; 1995; Nelson, 1988; 1993; Edquist, 1997) compare the innovation system focus on national industrial policy in different countries. The concept of the innovation system was first introduced in industrial literature in the late 1980s and subsequently became part of the vocabulary of national and international policymakers in the industrialized world (Metcalfe, 1995; Roseboom, 2004).

In addition to this, Tugrul et.al. (2002) suggested, that it is not only a collection of an organization but a group of agents who interact with each other to work logically as an agreement. Similarly, Francis (2006) pointed out that it is an analytical framework that examines the complex interactions between various actors and socio-economic institutions that shape technological and institutional opportunities. Thus, it is an interactive process where various agents, i.e. organizations and institutions involved in bringing a new product. Though this discussion draws three elements that are essential in the innovation system these are (Agwu, et.al. 2008): i) there is the involvement of organizations and individuals who are involved in generating, diffusing, adapting, and using knowledge, ii) When organizations interact to use knowledge leads to innovation in the form of

new products, processes, or services, and iii) elements of the institution that control how these relations and processes take place.

The basis of these assumptions includes several views on the concept of innovation, i.e. innovation can be done everywhere in society with the help of knowledge which promotes economic development. Similarly, in innovation processes, several of the actors are involved and knowledge is an essential component of the entire innovation process. It is also a linkage of different elements that lead the path of R&D through investments, knowledge generation, and the transfer of technology, etc. In addition, innovation includes novelty and technical change. The systems of innovation can be categorized into three broad-level national innovation systems, regional innovation systems, and sectoral innovation systems (Carlsson, et.al. 2002). It seems innovation is a complex process that involves various interactions and collaboration among different actors.

3.1. National Innovation Systems (NIS)

Christopher Freeman is a founder of the National Innovation System. According to him, the national innovation system is a network of organizations in both public and private sectors whose activities and interactions initiate, introduce, adopt, and commercialize new technologies (Freeman, 1987). The idea highlights that firms cannot be seen separately; firms are also part of networks that accentuate the linkages of formal and informal institutions. The system of innovation involves various elements and their relationships that help in the production and diffusion of knowledge and the national system of innovation covers these elements and relationships, either located within or rooted inside the borders of a nation-state (Lundvall, et.al. 2005). Thus, there are five features of the most NIS (Agwu et.al. 2008):

i. NIS tries to bring new linear and supply-driven thinking of research, technology transfer, and application by stressing interdependence and non-linearity in innovation processes and demand as a factor of innovation.

ii. NIS is inclined to innovation processes and systems that are context-specific of a particular country.

iii. NIS institution’s role encompasses norms, rules, laws, and organizations.

iv. Within the NIS emphasis is the shape and strength of interaction among the different actors.

v. It has been seen as a systematic instrument that can be used for policymaking to implement products or processes.

This concept provides a methodological background for the exploration of key elements and the relation of NIS in Agriculture and stresses that the system of innovation might be understood as a co-evolution of its various elements. Hence, NIS in agriculture provides a unique opportunity to assess these processes at different phases of NIS creation and progress.

3.2. Importance of the NIS concept in Agriculture

The Agricultural innovation system is derived from the concept of the national innovation system. The features of NIS and its definition implemented in agriculture sector. Tugrul et.al. (2002) stated that an agricultural innovation system consists of actors that jointly or individually contribute to the development, diffusion, and use of agriculture-related new technologies that affect the process of technological change in agriculture. It includes various organizations such as research and training organizations, educational institutions, funding organizations, civil society, farmers, etc. It also covers the complex associations among actors and networks. The figure shows the connections and relations between actors and networks in the agriculture innovation system.

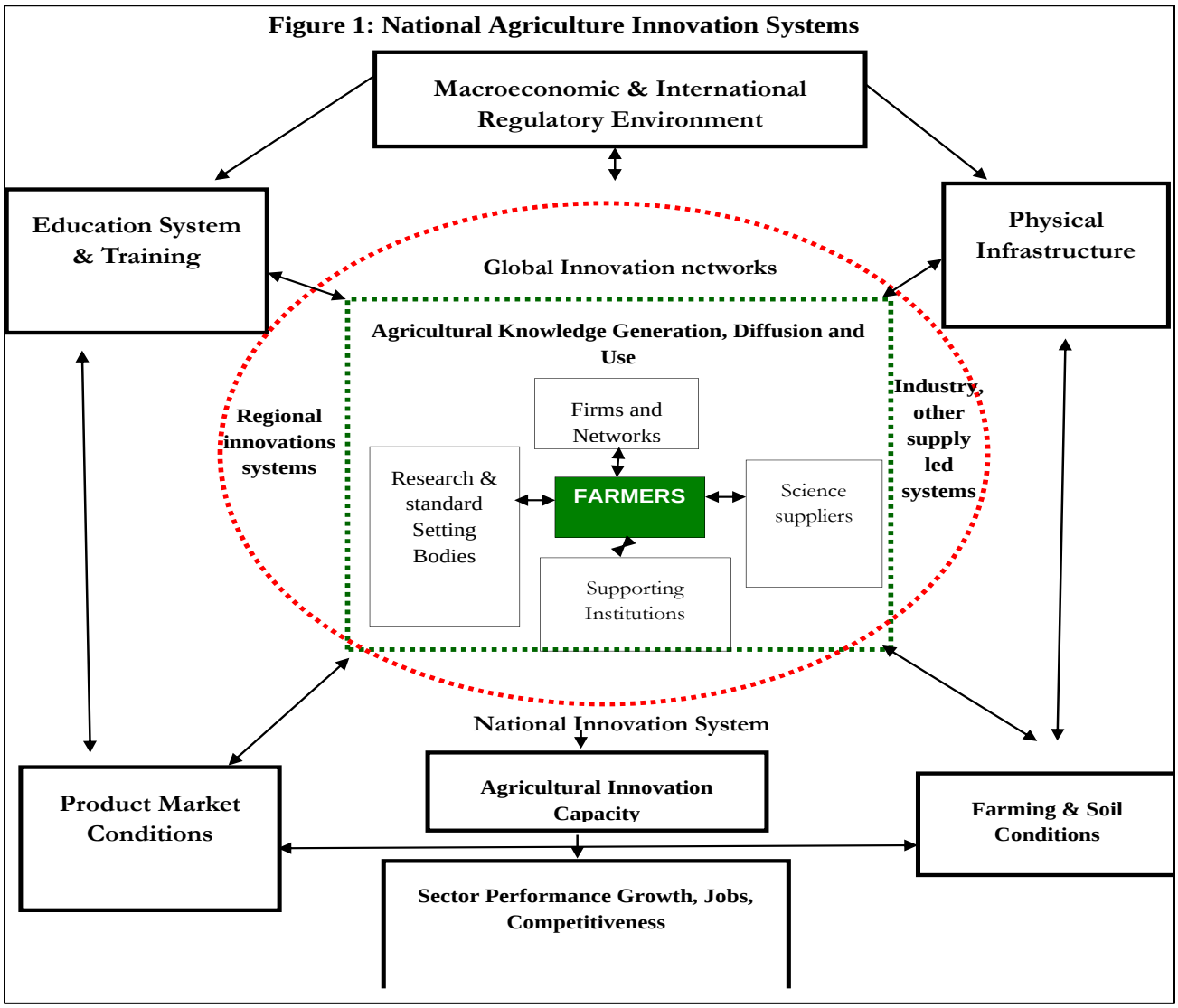
3.2.1. Concept of NIS in Agriculture

The concept can be understood with the help of an example of biotech technology in agriculture. The development of biotech clusters consists of two things i) the existence of first-class pre-commercial agriculture research in a state university or government laboratory, and ii) local systems to support and inspire entrepreneurial action to transfer ideas to products. It highlights the key role played by actors in such innovation systems. For instance, government funding to the National Institutes of Agriculture and state-level programs. Thus, three important organizations include at the National level, a research alliance with large, global agricultural firms with financial resources, and non-local venture capitalists. This relation can be seen in Figure No. 1.

In addition, the innovation system viewpoint on agriculture is essential for moving socio-economic study beyond the technological changes determined by the relative prices of land, labour, and other production factors (Speilman, 2005). Many scholars i.e. Hall et.al. 2001; 2002; Clark et.al. 2003

focused on how institutes play a role in research and innovation and introduced that innovation system to the study of agriculture and their research system in developing countries such as India. On the other hand, some scholars focused on technological prospects. For example, there is a study conducted in Argentina that covered social and economic transformation through the diffusion of zero-tillage cultivation (Ekboir et.al. 2002).

Figure 1 demonstrates the relations among farmers, international networks, and value chains (OECD, 1999). It is seen in India that farmers are isolated from the scientific knowledge system for the development of agriculture technologies as a lack of education comes into the way. The significance of farmers need not be exaggerated as the diffusion of technology and its success depends upon the user.



Source: Adapted from OECD, Managing National Innovation Systems, 1999.

4. Agricultural Innovation System of India and their R&D

A National Agricultural Innovation System consists of a network of organizations, enterprises, and individuals that bring a new product, and new processes through interaction with each other (World Bank, 2006). Similarly, agriculture R&D depends on its collaboration with numerous other actors to contribute to innovation. These actors may include universities, research institutions, user groups such as farmers, and other support structures.

4.1. Actors and Networks Involved in Agriculture R&D in India

Indian Council of Agricultural Research (ICAR) is one of the major actors involved in the agriculture research system which comprises a network of 189 centres and co-ordinated projects and provides funding and management in India. It comprises one Central University, 31 State Agricultural Universities, about 100 private R&D institutions, and several rural and women's universities. The state Agricultural Universities have several research centres that deal with specific crops and agro-ecological zones. Each of these research institutes has developed numerous technologies for agriculture and gets funding from the state government and other departments for instance DBT and DST.

Similarly, the private sector is one of the actors that contribute to the research and development in agriculture. The private investment has been increased in the agriculture sector. Mostly private investment occurred in seeds and machinery followed by pesticides, fertilizers, and food processing. Another important actor involvement is civil society such as research foundations and NGOs. The approach of civil society is to work with small farmers to provide accessibility to resources. In the public sector, the village extension workers from the Department of Agriculture (DoA) have a strong network to diffuse the technology at the field level in India. It functions as a source of information for farmers. The government has opened Krishi Vigyan Kendras in every state which is funded by ICAR yet the communication gap impedes the outcome; hence, it is not working well, especially in remote areas.

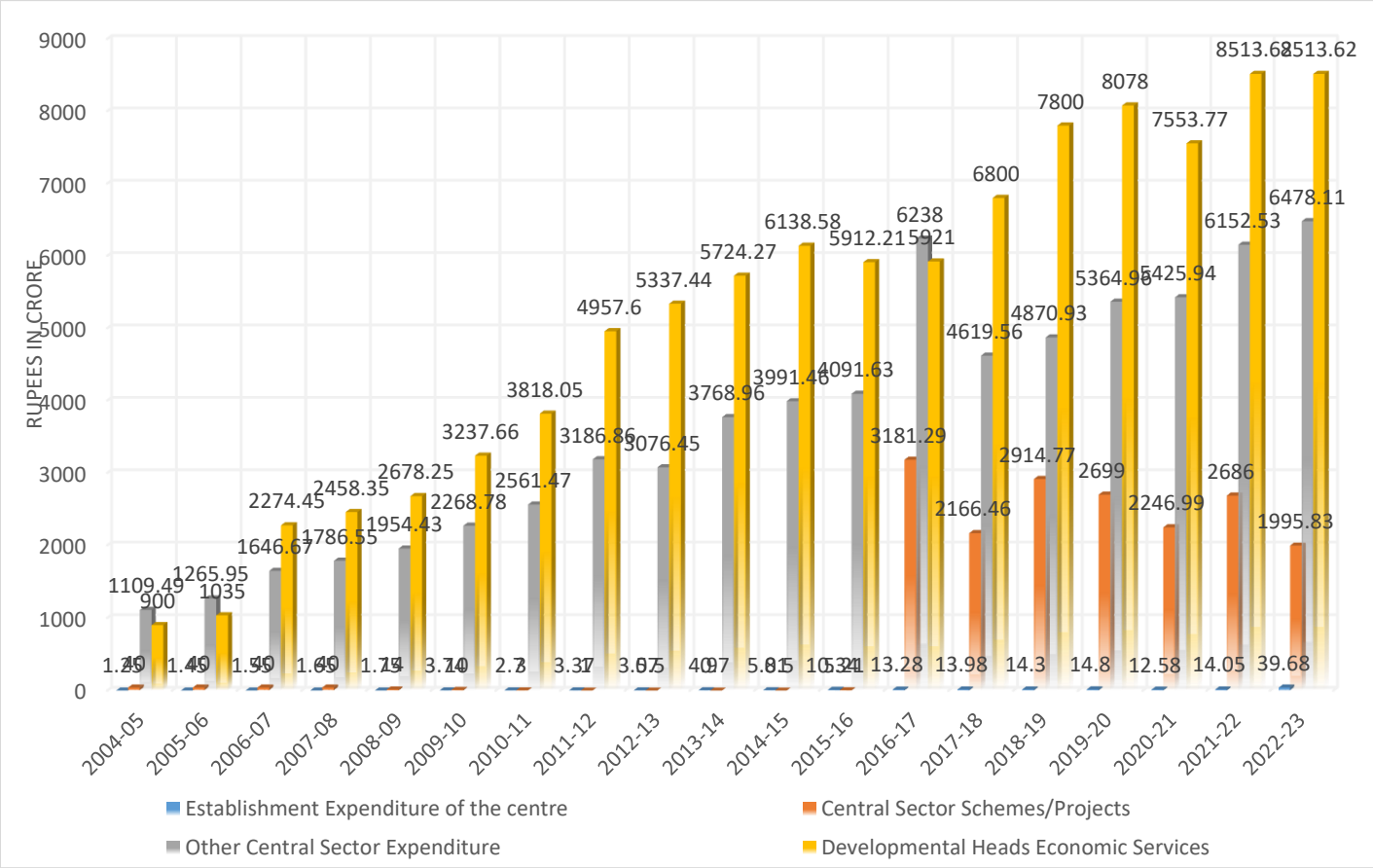
Further, Sulaiman and Hall, et.al. (2002) pointed out that the public and private sector extensions do not efficiently service in distant areas because many Kendras far from district headquarters. Therefore, the number of private extension service providers increased in the last two decades compared with the private sector. It comprises civil society organizations, farmers, extension providers, media, and agribusiness.

4.2. Investment of R&D in Agriculture

The investment in agriculture research and higher education has been increased in India. The international agricultural research institutions support to development in private R&D and public

research institutions generate the knowledge to develop their new commercial technologies. It also provides a training platform for scientists who are engaged in private research centers.

Figure:2. Trends of Government Budget Allocation for Agricultural Development



Source: Computed from various annual reports of ICAR.

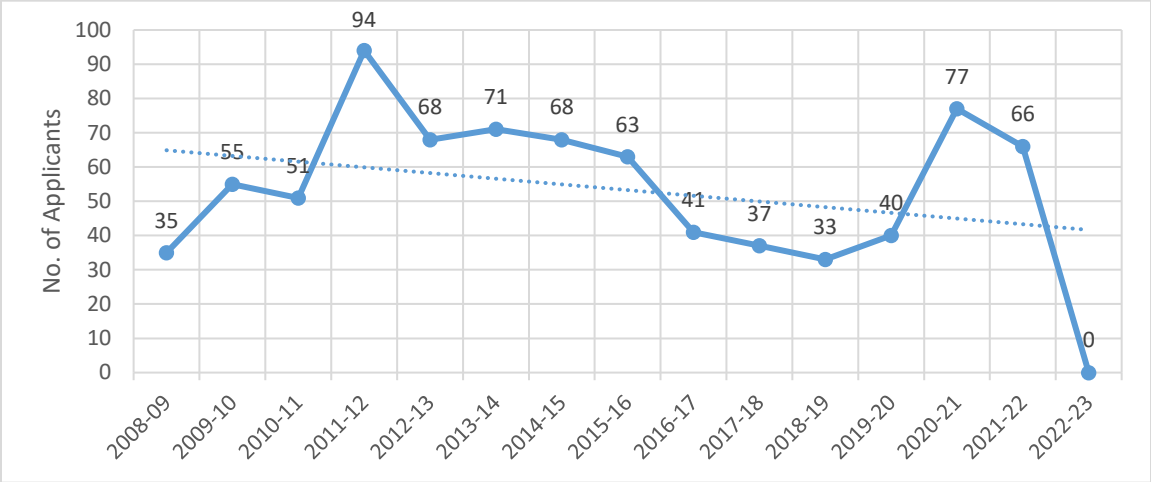
Figure 2 demonstrates the budget of the government on agricultural research and education. It can be observed, that the expenditure for agricultural research and education is increasing gradually. It has increased from Rs. 7553 crores to 8513 crores from 2020 to 2023 respectively.

4.3. Impacts of R&D on Crop Innovation

Plant varieties are one of the important sectors for agriculture where innovation is going on rapidly in India. Although, it is pointed out that, granted R&D in India has a critical examination of its applicability and suitability. The plant variety legislation of India presented a lengthy transition

period for the registration and protection of existing varietal products. However, it deems that a lack of confidence and negotiation capacity has prevented those advocating for the protection of extant varieties from achieving their intended goals. Recently the number of crop innovations in terms of seed has been increased which shows positive growth in agriculture. It can be seen from Figure 3 that during the period 2009-10 to 2014-15 registration fluctuated. During 2012-13 and 2013-14, the rate of innovation was stable and later declined. The highest application field in the year 2011-12. One of the reasons may be of more concern attached to the food security and IPR issues from 2000 to 2010.

Figure 3: Trend of ICAR Applicants for patents



Source: Computed through various reports of IPR.

ICAR Institution has major applicants filed for patents. However, the public sector dominates India's R&D system. Presently, the private sector agriculture system only focuses on those innovations that provide more benefits i.e. hybrid seeds, machinery, processing, etc. The involvement of the private sector helps to build up capacity in Indian agricultural R&D system. In this regard, India has supported its intellectual property rights (IPRs) rule in coordination with international agreements to encourage private-sector involvement in the development of agricultural technology. Furthermore, ICAR has put in place IPR guidelines geared to stimulate innovation by sharing research benefits with innovators. It would bring partnership with the private sector and help to the commercialization of technologies developed in the public sector.

5. Intellectual Property Rights in Agriculture Innovations

5.1. The Impact of IPR on Agriculture Innovation

In terms of patents in agriculture, the number of field applications fluctuated over the years. The details are shown in the table and discussed below:

Table 2: The Average trends of Patent filed and granted in the areas of agriculture engineering

Year	Number of Patent Applications Filed	Number of Patent Applications Granted
2004-05	190	67
2005-06	101	140
2006-07	1223	244
Avg.	504.67	150.33
2007-08	233	154
2008-09	88	20
2009-10	146	6
Avg.	155.67	60.00
2010-11	126	3
2011-12	183	3
2012-13	209	5
Avg.	172.67	3.67
2013-14	218	2
2014-15	226	2
2015-16	268	2
Avg.	237.33	2.0
2016-17	245	4
2017-18	338	125
2018-19	411	33
Avg.	331.33	54
2019-20	13	54
2020-21	11	79
2021-22	0	108
2022-23	0	0
Avg.	6	60.25

Source: Computed through various reports of IPR.

It can be observed from the figure that, the number of patent applications is high, but the number of patents granted is low. Similarly, one can see from the table that the number of patents granted is constant (3) in the years 2010, 2011, and 2014 in total. Similarly, table 3 shows the number of trademarks filed and registered on Agriculture, Horticulture, and Forestry Products and Grains.

Table 3: Average Trend of trademarks filed and registered on Agriculture, Horticulture, and Forestry Products and Grains

Year	Trademark Filed	Trademark Registered
2008-09	2310	1604
2009-10	2836	984
2010-11	3274	2165
Avg.	**2806.67**	**1584.33**
2011-12	3272	1114
2012-13	3612	873
2013-14	3856	1467
Avg.	**3580**	**1151.33**
2014-15	3818	818
2015-16	5341	1333
2016-17	5448	4315
Avg.	**4869.00**	**2155.33**
2017-18	4369	5690
2018-19	5130	5444
2019-20	5170	5029
Avg.	**4889.67**	**5387.67**
2020-21	8826	8354
2021-22	7784	4733
2022-23	8084	4177
Avg.	**8231.33**	**5754.67**

Source: Computed through various IPR reports.

In a sense, IPR is a tool to protect agricultural innovations that enable the innovators to exclude others from misusing the new product or process. Private firms that engage in agriculture R&D can thus be expected to count on this protection when making investment decisions. IPR is the only tool to attract the private sector to agriculture R&D (Kumar and Sinha, 2015).

5.1.1. Impact of Innovation on Food Grains

The impact of innovations can be seen in the production and productivity of food grains in the last two decades. The figure given below depicts the total foodgrains area, production, and productivity. As can be seen, the area is almost constant throughout the year but production and productivity are gradually increasing. For instance, in the year 2004-05, the production of food grains is almost 2000 lakh tonnes, and yield is also 2000 kg/ha. Similarly, in the year 2022-23, an average of 32 thousand lakh tonnes of production and yield 2494 kg/ha.

Figure 4: Total Foodgrains Area, Production and Yield

Source: https://upag.gov.in/dash-reports, 2024.

5.1.2. Comprehensive Analysis of Patent Granted, Productivity and Budget

The graph illustrates a regression analysis of patents granted over time, showing a downward trend in the number of patents granted from 2005 to 2017, as indicated by the regression line. The Regression Equation: Patents Granted = -3.64 * Year + 7386.98. However, it can be seen that after the 2017 patent granted, the number gradually increased. It may be because of the new IPR policy introduced in 2016 and the policy aimed to create awareness about the tools of IPR policy.

Figure 5: Regression Analysis for Patent Granted

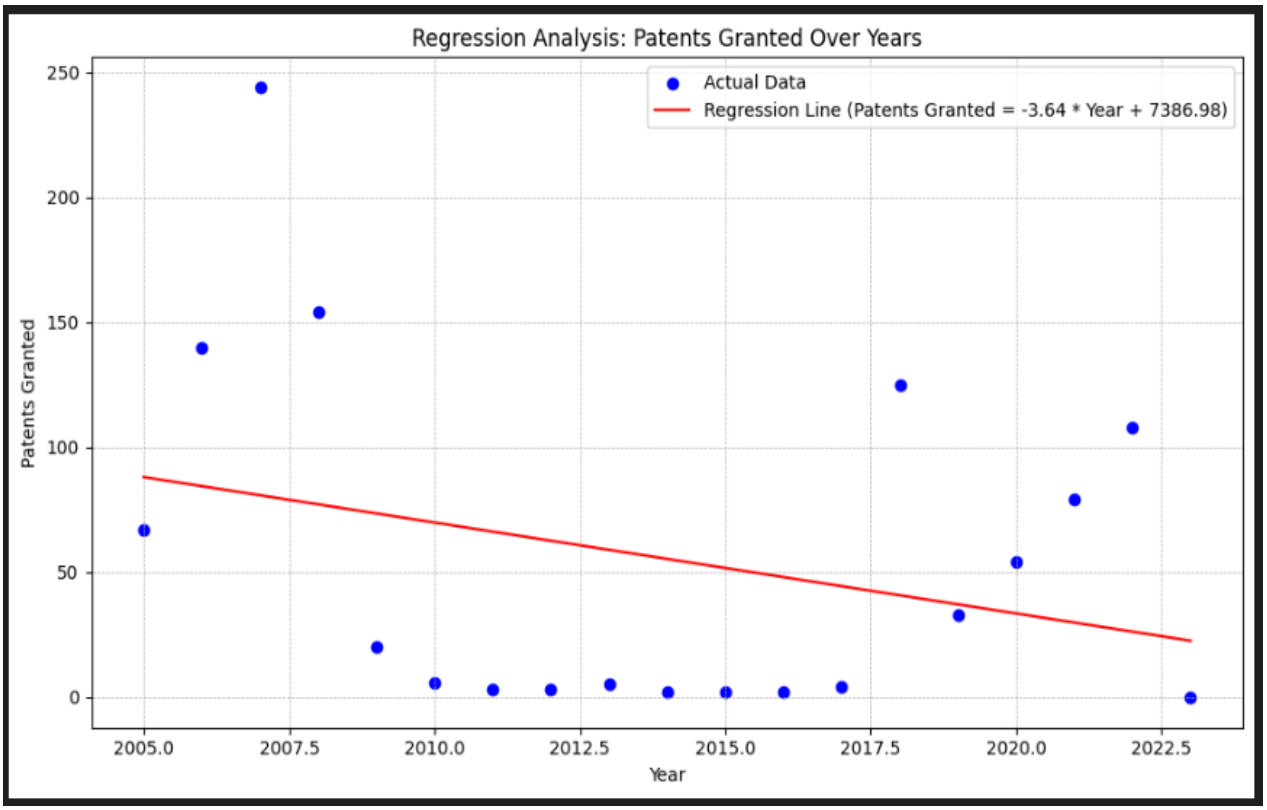
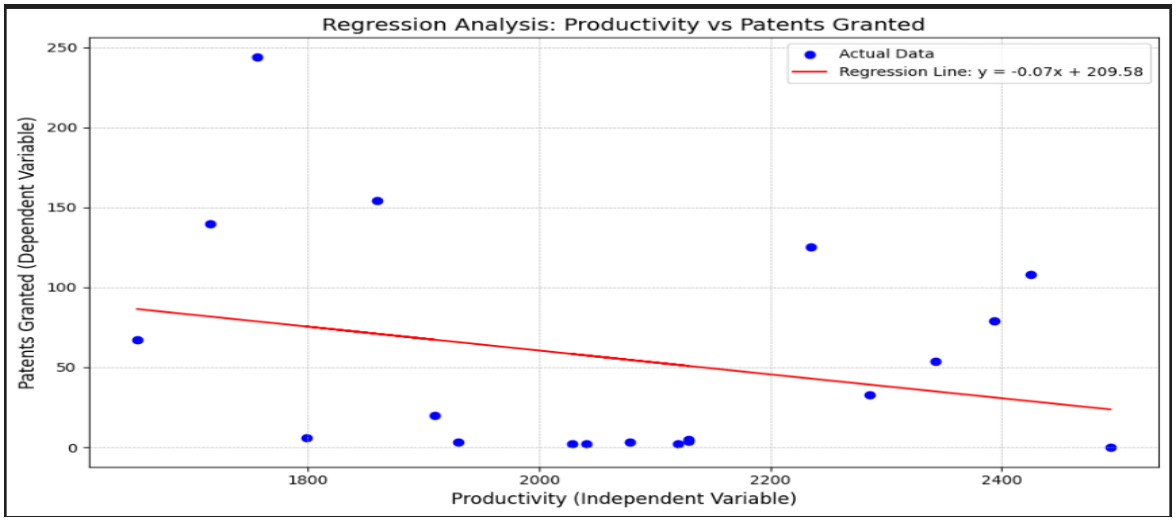


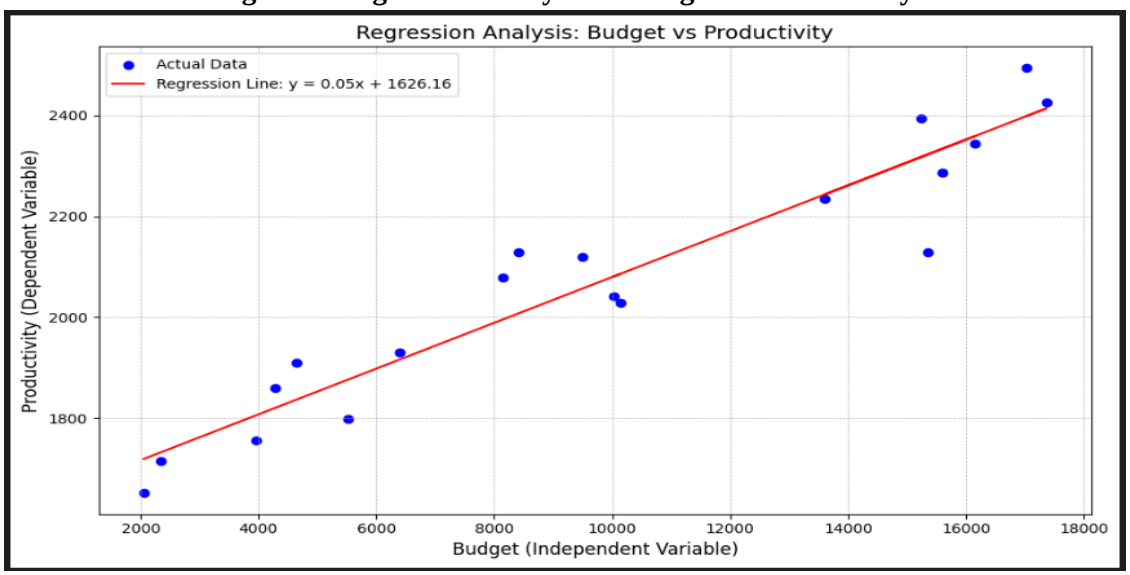
Figure 6: Regression Analysis of Patent Granted vs Productivity



The plot illustrates the variation in Patents Granted relative to Productivity, with the regression line indicating a subtle declining trend in the relationship. The Regression Equation: Patents Granted = -0.07 * Productivity + 209.58. This may be because farmers are less likely to adapt to

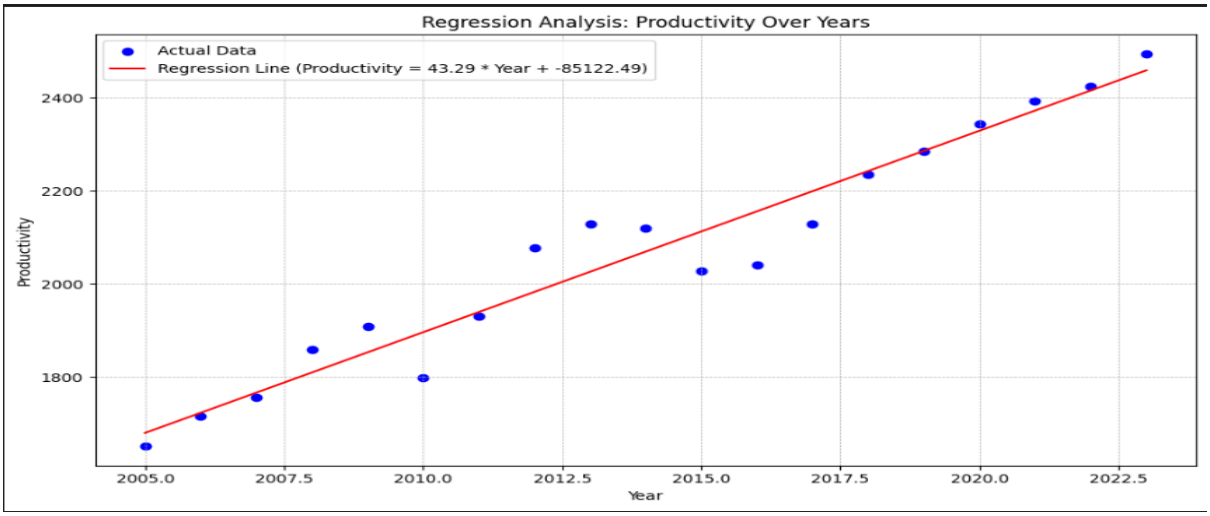
developed technologies. However, budget vs productivity is showing the positive results shown in graph below:

Figure 7: Regression Analysis of Budget vs Productivity



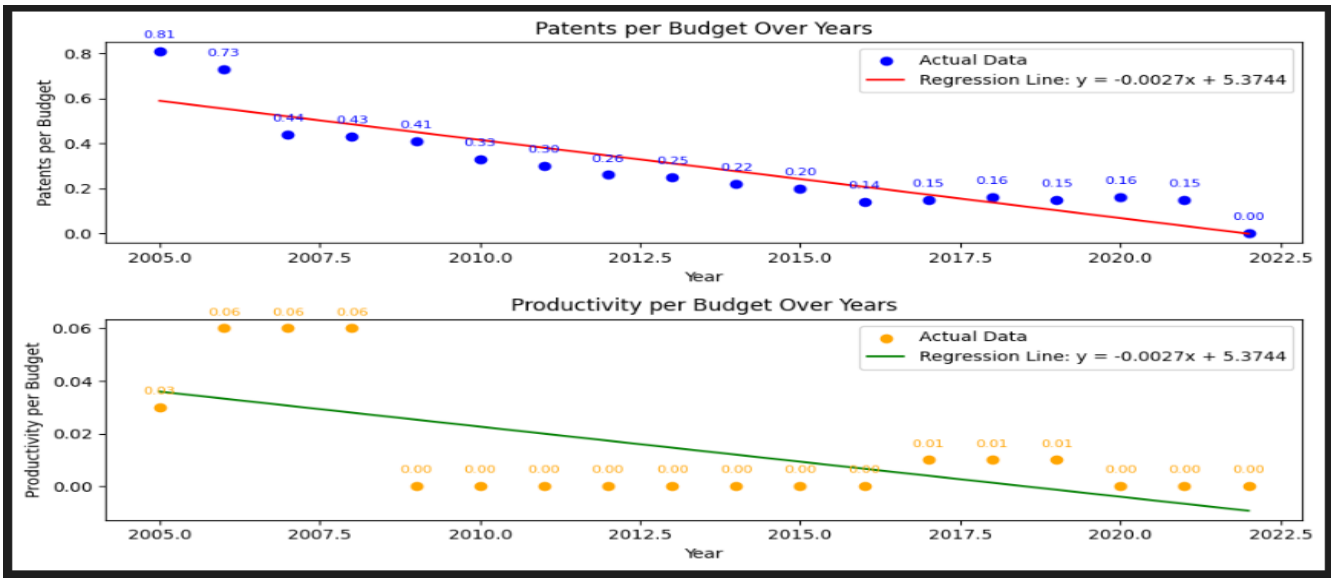
The graph illustrates the variation in Productivity relative to Budget, with the regression line indicating an upward trend in the relationship. The Regression Equation: Productivity = 0.05 * Budget + 1626.16.

Figure 8: Regression Analysis of Productivity



The graph shows the progression of Productivity over the years, with the regression line indicating a consistent upward trend. The Regression Equation is Productivity = 43.29 * Year + -85122.49. It is also important to check the efficiency of Patents, Productivity, and Budget.

Figure 9: Efficiency Metrics Over Years



The graph illustrates the trends in efficiency metrics over the years. Productivity per Budget shows a steady decline and stabilizing after 2015, while Patents per Budget remains consistently low throughout the period. The equation of Patents per Budget Regression Line is y = -0.0027x + 5.3744 and the productivity per Budget Regression Line: y = -0.0027x + 5.3744.

5.2. Intellectual Property Rights and Agriculture Innovation Management

The agriculture innovation management can be categorized into three parts i.e. innovation management patents, Technology Transfer/Commercialization, and professional services. The details of these classifications are discussed below:

Innovation Management Patents: In the year 2023-24, 78 new Patent Applications were filed in varied sectors of agriculture, and the cumulative number has now risen to 1455 applications. Indian Patent Office (IPO) published ICAR's 37 patent applications in this period and granted 47 patent

applications, taking a cumulative number of granted patents from ICAR is 455. In addition to this, 31 ICAR institutes are also involved in the protection of their innovation. Similarly, 31 varieties (19 extant and 12 new varieties) were filed at the Plant Varieties and Farmers' Rights Authority (PPV&FRA). There is a total of 21 plant varieties, and out of 21, 19 are extant and two are new varieties. In addition to this, there are other IPR tools used for Innovation Management at ICAR Institutes such as Copyright, Trademark, and Designs Application Filed (Cumulative) 159 (460) 29 (218) 14 (87) respectively. The cumulative of registered plant varieties is 1381. ICAR is also involved in other categories such as copyrights, trademarks, and designs.

Technology Transfer/Commercialization: ICAR Institute is also involved in licensing technologies to different public and private sector organizations and the mode of partnerships largely had been through formal Licensing Agreements. In 2023-24, 661 such license agreements were signed with 452 organizations for 379 technologies by 55 institutes. Out of these 661 licenses, 227 were IP protected.

Professional Services: ICAR institutes also provide consulting and research services to other organizations. Presently, 80 agreements signed by ICAR for consultancy in different subject matters and services are offered in 75 public and/or private organizations.

6. Conclusion

The Indian government has recognized science and technology as the major factor for the growth of agriculture. The method of agriculture innovation leads to sustainable agriculture growth through the linkages of actors and networks of innovation systems. It also integrates the mandates of reforms and emerging trends in agricultural development. India's Agricultural Innovation System is currently unable to address the challenges, i.e. access to technology by marginal and small farmers, environmental degradation, the involvement of different stakeholders, etc. because of uneven institutional development. The role of institutions should not stick with knowledge, it's also responsible for the diffusion of new technology. Thus, there is a need to create mechanisms such as a public-private partnership and interaction of farmers with scientists to combine and support their efforts so that they could enable the institutional changing process.

It is also important for the national agriculture research system to concentrate on better target research and to enhance the coordination of programs throughout the institutions thereby making the research agenda demand-driven. At the same, public R&D should be improved towards sustainable agriculture. The role of different actors is important to determine who plays what. In this regard, it is essential to examine the actual conditions of each case and determine who among several partners may take over one or more of these functions. In this context, the different roles from funding to the research, lab to land remain crucial, but who performs them and how is not pre-determined. Consequently, the concept of innovation is an empirical construct. It needs to plan who is involved in a specific innovation, who contributes to its development, and which rules and regulatory mechanisms are operating. It needs to be recognized and acknowledged by all R&D practitioners. It can be said that the strengthening of IPR in agricultural technology provides benefits that have encouraged more R&D and innovation. India has fertile and fragile climatic conditions to extend the area of activity.

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