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An Inquiry into Bhutanese Agriculture Research–Practice Gaps Using Rogers Innovation Adoption Attributes and Mode 2 Knowledge Production Features

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Abstract: Investigation into the relevance and utility of bridging gaps between knowledge and practice is necessary to justify such endeavors to public funding agencies. This study investigated the underlying causes of the research–practice gap in the Bhutanese context with the aim to realign the relevance of agricultural research and to enhance practice using Rogers innovation attributes on features of Mode 2 knowledge production features. Out of 233 articles published by three agricultural journal publishers, only 110 articles that met our criteria were included in this study. Principal component analysis (PCA) for 23 variables yielded five variables that contributed 90% of the total variation. The first two dimensions contained 39.34% of the total dataset inertia, which was significantly greater than the reference value (17.19%) obtained by simulating 959 data tables of equivalent size based on a normal distribution. Further, cluster analysis differentiated the observations into three distinct clusters that significantly differed in their variable descriptive values. The innovation attributes 'complexity' and 'compatibility' received the highest score, while 'observability' had the lowest score. Under innovation diffusion elements, 'time' and 'social system' aspects were the least considered, thus affecting the innovation adoption. The 'context of application' of innovation had the highest score (65%), whereas 'diffusion' of the knowledge under transdisciplinarity received the lowest score. Both the diversity of 'discipline' and 'organization' inclusion under heterogeneity received the lowest score. Informal communication and social dimension received the lowest score among the Mode 2 knowledge production variables. Bhutan followed conventional, linear, and unidirectional approaches to research and extension diffusion systems, by which research institutions innovate, and extension workers bring innovation to potential adopters. Bhutanese research policy and strategy must consider reframing relevant agriculture innovation systems to keep abreast of modern technology development.

Keywords: agriculture; research; practice gap; Bhutan

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1. Introduction

Knowledge is critical for the development of individuals, communities, and societies; we have strived for knowledge since the earliest days of civilization. The human desire to complete a given task in a better and more efficient manner has resulted not only in experimenting and producing more and better knowledge but also in the accumulation, evolution, and utilization of that knowledge for the betterment of humankind. Knowledge in ancient times, especially philosophies, was established either through experiences or encounters, which were then conveyed from generation to generation.

Investment in knowledge production and innovation has advanced economic performance and living standards. However, economic growth is also associated with environmental damage. Therefore, today's world faces substantial challenges that affect the sustainability of our food and agricultural systems due to the increase in the population and loss of biodiversity. This calls for new modes of knowledge production to address complex and urgent issues of global sustainability. Thus, the International Social Science Council (ISSC) pursues research on major future global change (Future Earth: Research for Global Sustainability) by bringing together multidisciplinary scientists and organizations (van der Hel 2016). Likewise, agricultural research is facing enormous constraints due to the rising cost of agricultural inputs, farm labor shortages, and the adverse impact of climate change, thereby affecting food security and sustainability. Knowledge creation and innovation are expensive processes that involve huge investments without assured return, especially in complex agriculture environments. Several researchers have highlighted growing concerns that academic research is becoming less useful for solving practical problems, widening the connection between theory and practice (Rasmussen et al. 2018; Van De Ven and Johnson 2006).

Expenditure on research has shown substantial positive impact on the number of publications but not on practice (Whalley and Hicks 2013). While it makes sense for the larger economies of the world to go beyond applied and adaptive research, it is critical for both developed and developing economies to maintain the balance between knowledge (innovation) creation and its application in the field to maximize return on the investment.

This maintenance of a greater balance between knowledge generation and application requires comprehensive background information on innovation in a specific context that is complex and multidimensional, which requires transdisciplinary competencies. In other words, the developmental process for innovation requires a highly competent team of experts from different disciplines to make the process beneficial and rewarding. However, innovation is central to achieving food security, ameliorating the adverse impact of climate change, and the sustainable management of natural resources. Consequently, researchers, policymakers, and funding agencies emphasize the need for robust innovation systems to scale up innovation that is not only viable economically but also sustainable environmentally.

Priorities for knowledge production change depending on the need, capacity, and availability of resources. The journey from knowledge to wisdom (Shrum and Macdonald 1985) is far from reach, and the gap keeps widening. Human intellectual temptations, desires for knowledge, and exploitation of nature for economic gains have become suicidal and disastrous, disrupting ecosystem balance and its critical functions. About 1.739 trillion USD (2.2% world GDP) is spent on space and defense research annually, of which the United States alone spends over 600 billion (Stockholm International Peace Research Institute 2018). Meanwhile, children in sub-Saharan Africa and South Asia suffer from hunger, malnutrition, and poverty (Webb et al. 2018). The Food and Agriculture Organization estimates that about 821 million people globally currently suffer from malnutrition, and 90% of farmers, who currently produce the food to feed the 7.8-billion-strong population, suffer from poverty themselves. Projections show that world food production must rise by 70 percent to feed the projected world population of 10 billion by 2050 (FAO 2018).

Although research in Bhutanese agriculture claims to significantly contribute to the development of the national economy, it is imperative that the research product remain meaningful, socially relevant, and practical. Quite often, knowledge in one situation becomes irrelevant or less relevant in another context due to differences in social, environmental, and cultural setup. A typical case is the citrus fruit-fly (*Bactocera minax*) and Asia citrus psyllid (*Diaphorina citri*) control program, which used pesticides. While these programs significantly controlled these citrus insect pests, the methods were inconsiderate of Buddhist sentiments. Therefore, many of the Bhutanese growers were not keen on the spray program. In this sense, innovation without socio-economic and cultural consideration tends to only result in short-term outputs with intangible economic benefits, thereby failing to justify public funding. Such disparities between existing knowledge and actual field adoption create a gap between research and practice, throwing into question the relevance of research.

The productivity and efficiency of agriculture research remain at the forefront of concern for many national and international decision-makers. Research organizations continuously generate innovative technology for farmers to adopt. Bhutan initiated an agriculture research system in the 1960s with the establishment of Centers for Agricultural Research and Development (CARD). Currently, four regional Agricultural Research and Development Centers (ARDCs) in different agro-climatic zones, namely, ARDC Wengkhar (east), ARDC Bajo (West Central Region), ARDC Yusipang (West), and ARDC Bhur (South) cater to the needs and aspirations of their regional clients (Dearing 2009). Most of the available agricultural innovations in Bhutan appear to be obsolete in the current context, as problems and opportunities in field situations are highly volatile, uncertain, complex, and ambiguous. For example, several released crop varieties (cereals, vegetables, and fruits) for commercial cultivation that were approved as innovations by the Technology Release Committee (TRC) of the Bhutan Department of Agriculture appear obsolete in the current context. Despite the huge cost incurred in the development and identification of these innovations, centers also spend resources on the maintenance of released technologies. Such innovation needs further assessment in the current context.

The development and adaptation of innovation in a complex environment system requires consideration of several factors at the various levels of its developmental phases. The long-term sustainability of an institution or organization (either private or public) depends on the generation of innovation that is not only economically viable but also advantageous over the existing technologies while sitting within the existing social context and policy framework (Brinkerhoff and Goldsmith 1992). However, such practices are more appropriately applied to the private sectors, companies in developed countries lacked a formalized process to guide innovation (Alon and Elron 2015; Neese 2017). Similarly, the research findings, inventions, or innovations developed by the universities and research organizations lack comprehensive packages or guides to develop innovations that are contextualized and situation-driven, thus leading to a wider gap between knowledge in stock and actual applications. Often, this is because a given generation of innovations is focused on a specific, singular stage of the value chain rather than considering them across all development phases (Vanclay et al. 2013).

1.1. Innovation Adoption and Attributes

Contextual and contemporary innovations remain relevant to a specific area during their stipulated period. The limited focus on their long-term relevance, dynamism, and client perceptions and aspirations make innovations less productive. The traditional disciplinary research has narrowed and deepened specializations, making research less relevant to outsiders or society (Krishnan 2009). The innovation generation process (knowledge production mode), innovation attributes, and elements of innovation diffusion directly affect the adoption of an innovation (Rogers et al. 2014). Also, the characteristics of potential adopters such as knowledge, perceptions, and attitudes, as well as external environmental factors, affect adoption decision-making processes (Meijer et al. 2015). In fact, inadequate attention paid to the end-user characteristics and the interactions between different variables influences adoptions (Kristian Häggman 2009).

Although several studies have used frameworks for adoption study, there lacks a consistent definition and precise measurement of the constructs (Wisdom et al. 2014). Little is known, however, about the factors related to decisions to adopt innovations and how the likelihood of adoption of innovations can be increased with social relevance. Innovation adoption requires building trust and acceptance among the stakeholders involved. This trust between the stakeholders and acceptance of the innovation generated demands involvement of the end-user right from the initial stage of innovation development (Tress et al. 2005). In fact, researchers and policymakers contend that social capital and stakeholder management ability are associated with performance (Andrews and Brewer 2013). A paradigm shift from the traditional mode of knowledge production (Mode 1) to 'Mode 2'—mode of knowledge production—is emphasized for research and societal relevance

(Newig et al. 2019). Emphasis on moving away from traditional scientific evidential criteria towards actual practice environments would produce more relevant and actionable research tailored to practice in the context of application (Rasmussen et al. 2018).

1.2. Knowledge Production

Knowledge plays a significant role in today's world economy. The practicality and application of knowledge in context and the shift of knowledge production from Mode 1 (classical/traditional university conventional form) to Mode 2 (knowledge production in the context of application) has gained attention over the past two decades. Knowledge of technology and process can be best applied only when all associated factors, including social, political, economic, and physical contexts, are well considered. Along with labor and capital, knowledge is now considered as one of the main factors of production (Alekseevna 2014). The Organization for Economic Co-Operation and Development (OECD) estimated that more than 50 percent of gross domestic product (GDP) is knowledge-based (OECD 1996). While theoretical broadening of the knowledge base must continue, it is imperative that practical application and the realization of change and impact for the society are set as the priority. Engagement with the impacts of knowledge generated through research systems remains highly fragmented, scattered, and often difficult to access.

1.3. Mode 1 Knowledge Production

'Mode 1' knowledge production refers to the conventional form of knowledge production, in which the focus is on scientific discovery, and the problems are defined by the scientific community in an academic context outside of the context of practice (Frost and Osterloh 2003). Usually, this mode of knowledge production results in the publication of scientific journal articles or conference presentations to homogeneous groups of the scientific community based on discipline. The 'Mode 1' approach to knowledge production is usually prescriptive and very rarely open for discussion within the community, other than for one's own discipline or interests, and the main objective is to advance one's academic career or obtain scholarly endorsement (Frost and Osterloh 2003).

1.4. Mode 2 Knowledge Production

The idea of 'Mode 2' knowledge production was first discussed by Gibbons et al. (1994). This mode of knowledge production defines the context of application, involving both academicians and practitioners. In contrast to 'Mode 1', it is transdisciplinary and involves specialists from different fields to work on and solve the problems from different angles (Frost and Osterloh 2003). Unlike the conventional 'Mode 1', knowledge production occurs in various organizations (universities, government agencies, research centres, high-tech companies, consultancies, etc.) that lead to heterogeneous adoptions and practices. Additionally, the Mode 2 process involves dialogue and offers opportunities to incorporate multiple opinions (reflexivity). The problems are democratically defined in collaboration with end-users and involve other specialist stakeholders. Knowledge validation occurs through use and impact assessment in the economic, political, social, and cultural spheres in addition to traditional peer review systems (Hessels and van Lente 2008; Nowotny et al. 2003).

1.5. Mode 3 Knowledge Production

The Mode 2 knowledge production concept has gained popularity with contemporary science practice. However, it suffers from several conceptual issues, requiring investigation of its constitutive claims (Hessels and van Lente 2008). Nevertheless, Mode 2 knowledge production constitutive claims such as social accountability, context, transdisciplinary, problem orientation, reflexivity, and practice focus have emerged as the extra-scientific criteria to determine priority for research and funding. Thus, the concept of Mode 3 knowledge production emerged to integrate the principle of knowledge production and application with quality assurance (Carayannis et al. 2016). The classical knowledge-based economies are mostly market-driven and do not recognize natural resources and sustainability. Several helix innovation models emerged, as the understanding of knowledge production transitioned to include environment and ecology in addition to economy, society, and democracy (Harkins and Kubik 2006).

According to the relational model of social institutions, each constituent element of a social network is made up of several types of interlocking networks among the actors of various social relations and role systems. Unpacking of this social phenomenon is critical to changing the way one perceives individuals, actions, cultures, and entire social processes (Mohr and White 2008).

1.6. Problem Statement and Research Questions

Across the globe, public funding agencies have been called upon to demonstrate scientific and societal impact. Research institutions often face difficulties in securing public funds, subsequently affecting the generation of innovation. Research organizations have both an obligation as well an interest to report the richness and variety of social and economic benefits that result from investment in the research.

Lack of transparency and accountability for public resources meant to bring about societal benefits has led to a questioning of public funds expenditure on research. Technology on the shelf remains only partially adopted and not much impact (developments) has been realized, because complex research issues were often addressed with a linear reductionist approach. Single-disciplinary problem-solving approaches were too narrow and often inconsistent with the problem phenomenon in field situations, leading to doubts about research relevance, poor adoption, and accountability. Mode 2 knowledge production features, although critiqued over the past two decades, enhance not just the societal relevance of research, but also accountability for public funding.

Studies on innovation adoption in diverse disciplines have used the popular Rogers innovation diffusion theory (Rogers et al. 2014) to synthesize and gauge the efficiency of innovation adoption for over 30 years (Dearing 2009; Kapoor et al. 2013, 2014; Sahin 2006). Although, to a certain extent, Rogers innovation attributes overlap with the Mode 2 knowledge production process, many of the constitutive features that enhance the social relevance, reflexivity, embeddedness, accountability, and complexity of innovations remain unaddressed and understudied. This issue of non-adoption of innovation in the Bhutanese context was studied from two dimensions: the innovation generation process (mode of knowledge production) and the nature of the innovation (innovation attributes).

Bhutan's innovation and research development receives less priority due to its lack of guaranteed return and long duration. For example, less than 5% of the annual budget outlay for the Agriculture Research & Development Center (ARDC) at Bajo is for research and innovation (ARED-DoA Bhutan 2021; Bhutan National Council 2014). In fact, agriculture research receives about 0.7% of agricultural gross domestic product (GDP), which is much less than the international standard[1] (Christensen et al. 2012).

Therefore, this study explored agriculture research in Bhutan by applying Mode 2 knowledge production features to our selected articles and by evaluating innovation attributes and innovation diffusion elements to identify the gap that affects the adoption of an innovation. The specific research goals this study established were as follows:

1. Identify the research and adoption factors that contributed to the research–practice gap in the Bhutanese agricultural context over the past two decades
2. Identify the topical divides among public research institutes (PRIs) against the common vision of narrowing the research–practice gap.
3. Identify the way forward for PRIs to enhance societal relevance and accountability and sustain agriculture research and innovation.

2. Methodology

Setting research priority frameworks and agendas must incorporate social dimensions and accountability from conception to implementation and impact engagement. The relevance of research to generate technology depends on the types of technology generated and its development process (knowledge production). More importantly, low innovation adoption occurs when the technology generated is not what farmers want or if they are unaware of existing technologies. User acceptance and confidence are crucial for the development of innovation, and the involvement of the user in the development system enhances technological adoption (Taherdoost 2018). Both Rogers innovation attributes and Mode 2 knowledge production features were deployed to assess and synthesize existing agriculture technological interventions.

Enhanced adoption occurs when the innovation generated remains relevant to end-users. Innovation relevancy improves when the innovation processes engage all relevant stakeholders from across backgrounds during the knowledge production process. As many as 27 innovation attributes have been identified to influence adoption (Chor et al. 2015; Tornatzky and Klein 1982); however, in the first part of this study, we used Rogers five attributes, i.e., relative advantage, compatibility, complexity, trialability, and observability, and four innovation diffusion elements, i.e., time, social systems, innovativeness, and communication channels, to assess the usefulness of the innovation generated. The second part of this study deployed (Coghlan 2014) Mode 2 knowledge production dimensions, namely, context of application, transdisciplinarity, heterogeneity, communication channels, quality control systems, and social accountability. Under transdisciplinarity, we identified three areas: problem-solving effort, knowledge acquired, and diffusion. We included disciplinary heterogeneity and organizational diversity under heterogeneity, while communication channels consisted of formal (academic) and non-formal (non-academic) publications that engaged stakeholders in the research process across the project period. Cognitive and social dimensions were used for quality control assessment, whereas result interpretation, diffusion, problem definition, and priority were the dimensions considered for the assessment of social accountability. A detailed description of the features and their variables is presented in Table 1.

Table 1. Description of variable score.

Variables	Variable Category	1 (Never)	2 (Occasionally)	3 (Often)	4 (Usually)	5 (Always)	Explanation
Relative advantage (RA)		Not at all	Some what	Fairly	Highly	Extremely	The degree to which an innovation is perceived as being better than the idea it supersedes
Compatibility		Not at all	Some what	Fairly	Highly	Extremely	The degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters
Complexity		Not at all	Some what	Fairly	Highly	Extremely	The degree to which an innovation is perceived as relatively difficult to understand and use
Trialabliity		Not at all	Some what	Fairly	Highly	Extremely	The degree to which an innovation may be experimented with on a limited basis
Observability		Not at all	Some what	Fairly	Highly	Extremely	The degree to which the results/outcome of an innovation are visible to others
Innovation (innovativeness)		Not at all	Some what	Fairly	Highly	Extremely	Ideas, practices, or projects that are perceived as new by an individual or other unit of adoption
Communication channels		Not at all	Some what	Fairly	Highly	Extremely	Processes by which participants create and share information with one another to reach a mutual understanding

Table 1. *Cont.*

Variables	Variable Category	1 (Never)	2 (Occasionally)	3 (Often)	4 (Usually)	5 (Always)	Explanation
Time		Not at all	Some what	Fairly	Highly	Extremely	Time required for an innovation to disseminate and adopt
Social systems		Not at all	Some what	Fairly	Highly	Extremely	Sets of interrelated units engaged in joint problem-solving to accomplish a common goal
Context of application		Not at all	Some what	Fairly	Highly	Extremely	
Transdisciplinarity	Problem solving effort	Not at all	Some what	Fairly	Highly	Extremely	Involvement of relevant stakeholders in problem-solving effort
	Knowledge	Not at all	Some what	Fairly	Highly	Extremely	Generation of multidisciplinary knowledge of the context
	Difussion	Not at all	Some what	Fairly	Highly	Extremely	Involvement of stakeholders in diffusion of innovation generated
Heterogeneity	Disciplines	Not at all	Some what	Fairly	Highly	Extremely	Involvement of stakeholders from different disciplines in addition to traditional science from university departments
	Organizational diversity	Not at all	Some what	Fairly	Highly	Extremely	Involvement of different organizations outside academic organizations
Communication	formal	Not at all	Some what	Fairly	Highly	Extremely	Type and quality of academic publications in the form of peer-reviewed journal articles, dissertations, pamphlets, leaflets, etc.)
	informal	Not at all	Some what	Fairly	Highly	Extremely	Dissemination of findings to different stakeholders in addition to formal academic publications, such as community engagements, demonstrations, exhibitions, etc.
Quality control	Cognitive	Not at all	Some what	Fairly	Highly	Extremely	Academic rigor and soundness of the innovation and generation process
	Social dimension	Not at all	Some what	Fairly	Highly	Extremely	Multi-dimensionality (socio-economic, political, cultural)
Social accountability	Result interpretation	Not at all	Some what	Fairly	Highly	Extremely	The inclusion of social issues in result (environment, health, privacy, public interests)
	Result diffusion	Not at all	Some what	Fairly	Highly	Extremely	Result dissemination and reach to wider public
	Problem definition	Not at all	Some what	Fairly	Highly	Extremely	Collective definition and identification through involvement of stakeholders for collective responsibility
	Research priorities	Not at all	Some what	Fairly	Highly	Extremely	The importance of research based on capacity and need

2.1. Search/Identification and Screening

We first identified appropriate digital sources of journal articles and examined search results. We considered all available online Bhutanese journal articles on agriculture and adjacent subjects (forestry and livestock) published in Bhutan. The articles were retrieved from (1) the Renewable Natural Resource Journal, currently archived by the Bhutan Journal of Agriculture (https://www.bja.gov.bt/archive/, accessed on 20 January 2020) of the Department of Agriculture and published by the Renewable Natural Resource Research

Council of Bhutan (CoRRB); (2) the Bhutan Journal of Agriculture (https://www.bja.gov.bt/, accessed on 20 January 2020), published by the Bhutan Department of Agriculture; (3) the Bhutan Journal of Natural Resource & Development (http://www.bjnrd.org/index.php/bjnrd, accessed on 20 January 2020), published by Royal University of Bhutan. The list of journals is attached as Supplementary Materials. Based on the inclusion criteria, the citation of the selected articles was imported to the endnote library.

2.2. Inclusion Criteria

1. Published in the Bhutanese journals
2. Only peer-reviewed journal articles
3. Publicly accessible journal articles through websites or webpages
4. Research pertaining to crops and adjacent subjects
5. Published in the English language
6. Published between the years 2006 to 2020

2.3. Evaluation Criteria and Scoring System

The selected articles were screened and checked for different dimensions of innovation attributes, diffusion elements, and the Mode 2 knowledge production features. We provided an unweighted score ranging from 1 to 5 (1 = Rarely, 2 = Occasionally, 3 = Often, 4 = Usually, 5 = Always) based on the degree of inclusion of the features and attributes. The resulting score data were checked for consistency.

2.4. Data Analysis

The polarity of the scale data was checked, and bipolar and opposite codes were re-scored in the same direction (1 to 5) to enhance the scoring consistency. For example, the complex articles were rated high for data, but complex innovations are usually less adopted. We performed principal component analysis (PCA) using the Factoshiny package (Vaissie et al. 2021) in R (R Core Team 2014) to identify the main factors and their contributions. We also analyzed the structure and their spatial distribution of the observations and the principal factors or the variables. We extracted the most vital information and simplified the dataset description (Abdi and Williams 2010). The component with an eigenvalue greater than one was used for factor extraction using Kaiser's criterion (Kaiser 1960). The contribution of an observation (j) to the component (k) was obtained as the ratio of the squared factor score of the observation to its corresponding eigenvalue (Equation (1))

$$Contrib\ j,k = \text{f2}j, \frac{k}{\sum j}\text{f2}j,k = \text{f2}j, \frac{k}{\mu 2} \quad (1)$$

where $\mu 2$ is the eigenvalue of kth component.

The quality of factor representation was computed using Equation (2) followed by the computation of the expected average contribution (cut-off point) via Equation (3) (Kassambara 2017).

$$Contrib = \frac{[(C1 * Eig1) + (C2 * Eig2) + (C3 * Eig3) + \ldots\ (C23 * Eig23)]}{Eig1 + Eig2 + Eig3 \ldots + Eig23} \quad (2)$$

where $C1$, $C2$, $C3 \ldots$ $C23$ represent their corresponding contributions of the variable PC1, PC2, PC3 … PC23) and $Eig1$, $Eig2$, $Eig3 \ldots$ $Eig23$ are the eigenvalues of PC1, PC2, PC3 … PC23, respectively.

The expected average contribution of a variable for PC1, PC2, PC3 … PC23 is

$$Cut-off = \frac{[(23 * Eig1) + (23 * Eig2) + (23 * Eig3) + \ldots (23 * Eig23)]}{Eig1 + Eig2 + Eig3 \ldots + Eig23} \quad (3)$$

The variables (from innovation attributes, innovation diffusion elements, and Mode 2 dimension) that contributed to the variation were identified, selected, and described by comparison with the descriptive analysis. We also conducted individual within-group PCA to identify and compare the variation within the groups. Further, we performed cluster analysis and assessed variable contribution and variable descriptive to each cluster and their representation by comparing global frequency (total number of times the variables' descriptive were assigned) to the internal frequency for the given cluster (number of times the variables descriptive was assigned within the cluster).

3. Results and Discussion

Out of 233 articles published by three agricultural journal publishers, only 110 articles met our criteria and included in this study. The Renewable Natural Resource (RNR) Journal published 138 peer-reviewed articles, of which 58 were related to crop science. Similarly, the Bhutan Journal of Natural Resource and Development (BJNRD) published 54 agricultural articles, of which 13 articles were included. All 41 articles published by the Bhutanese Journal of Agriculture (BJA) were included in the study, as the articles were related to crop science. The PCA analysis that we conducted identified their information content and structure. The components were further described using quality of representation and contribution to the first four dimensions. The variables were classified into three distinct clusters, with each described by the descriptive value of the observations. When compared with their descriptive statistics to make sense of the structure, the results indicated that most of the innovation attributes were considered in the papers, while innovation diffusion elements and Mode 2 knowledge production features were lacking.

3.1. Principal Components and Variable Significance

Principal component analysis is a powerful analytical method used in various disciplines (Abdi and Williams 2010; Bro and Smilde 2014). PCA enables us to summarize and visualize the information contained in a dataset using multiple inter-correlated quantitative variables (Kassambara 2017) and thus reduce dimensionality and enhance interpretability without losing information (Jolliffe and Cadima 2016). Out of 23 variables (from Rogers innovation attributes, diffusion elements, and Mode 2 knowledge production features), '*research priorities*', '*context of application*', '*problem-solving effort*' and 'relative advantage' were the variables that positively contributed to the variation without losing information. PCA indicated strong relationships between variables, suggesting the number of dimensions to be studied. The first two dimensions explained 39.34% of the total dataset inertia, which was significantly greater than the reference value (17.19%) obtained by simulating 959 data tables of equivalent size based on a normal distribution. The amount of inertia presented by these four axes was greater than those acquired by random distribution (55.28% against 31.27% 0 of 0.95 quantile, thus carrying real information) (Figure 1).

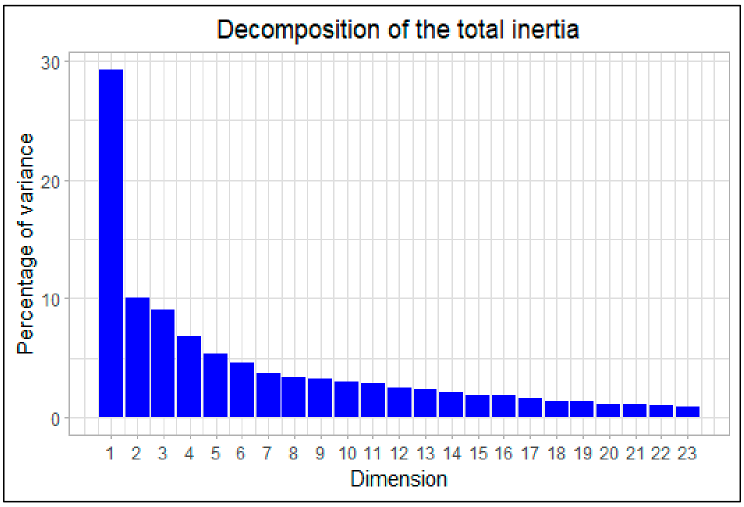

Figure 1. Decomposition of the total inertia.

3.1.1. Quality of Representation for the Variables/Factors

The quality of the representation is depicted by the squared cosine (cos2) of the variable component with an observation. Cos2 shows the contribution of a variable to the squared distance of the observation to the center; it corresponds to the square of the cosine of the angle from the right triangle made with the origin. All 23 variables under study showed diverse levels of quality representation. On the positive coordinate (upper right quadrant), determinants of innovation adoption variables '*context of application*' peaked at the cos2 values, followed by '*research priorities*' and '*relative advantages*'. On the other note, '*complexity*', followed by '*cognitive*' and '*trialability*' had low cos2 values, indicating the inferior quality of the representation. On the lower right quadrant, '*informal communication*' followed by '*disciplines*', '*organizational diversity*,' '*social system*', and '*social dimension*' were strongly indicated for their quality representation. In contrast, '*formal communication*', followed by '*observability*' and '*diffusion*', were poorly represented. The cos2 representation of dimensions 1 and 2 is shown below in (Figure 2).

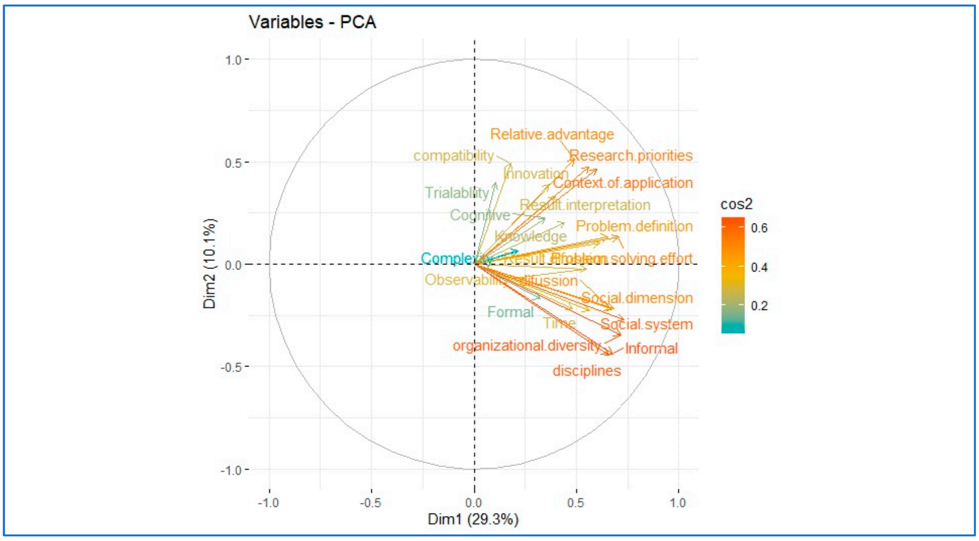

Figure 2. The quality of representation (cos2) plot for the first two dimensions.

3.1.2. Contribution to the Variance by the Factor Variables

'*Context of application*', '*problem-solving effort*', and '*relative advantage*' ranked high on the positive coordinate of dimensions 1 and 2 (Figure 2). This indicates that most of the articles focused on solving an issue in the Bhutanese context. '*Compatibility*' and '*trialability*' attributes followed by '*research priorities*' were also considered in the articles published. Of the five innovation attributes, the variables that contributed to the total variability were '*relative advantage*' and '*observability*' of innovation in the first dimension. Variables such as '*relative advantage*' and '*compatibility*' contributed about 32% of the variability in dimension 2, followed by '*trialability*'. In dimension 3, '*trialability*' contributed to maximum variability (32%), followed by '*compatibility*' and '*complexity*'. Similarly, in the innovation diffusion element group, '*social system*' (53%) followed by '*communication channel*' (32%) and '*time*' (21%) factor contributed to the variability in dimension 1.

Variables such as '*organizational diversity*' under group heterogeneity and '*problem-solving effort*' under group social accountability accounted for the maximum contribution of the variance for dimension 1, followed by '*social dimension*', '*informal communication*', '*disciplines*', '*diffusion*', and '*problem definition*'. The factor variables '*result diffusion*', '*research priorities*', and '*context of application*' together contributed about 32% of variability to dimension 1. Similarly, for dimension 2, much of the variability was contributed by the variables '*relative advantage*' and '*compatibility*', followed by '*context of application*', '*disciplines*', '*research priorities*', and '*informal communication*'. For dimension 3, the highest contribution to the variance was made by '*innovation*', followed by '*knowledge*' and '*trialability*' under the innovation attribute group. '*Formal communication*' contributed the highest variability in dimension 4. The overall contribution of the variables to the total variability is explained by the correlation plot (Figure 3A) along with the group variables contributing to dimensions 1 and 2 (Figure 3B).

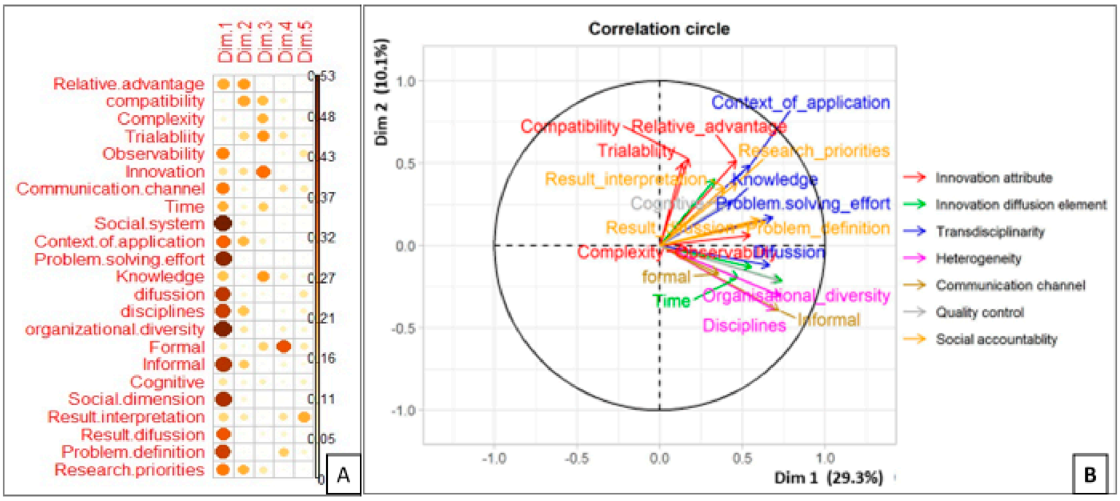

Figure 3. Contribution of 23 variables to the first five dimensions (**A**) and the correlation circle of dimensions 1 and 2 (**B**).

The dimension, contribution, and cos2 of the first 10 variables for the first three dimensions are shown below in Table 2.

Table 2. Contribution and cos2 for the first three dimensions for the top ten variables.

Top 10 Variables	Dim.1	Ctr	Cos2	Dim.2	Ctr	Cos2	Dim.3	Ctr	Cos2
Relative advantage	0.490	3.561	0.240	0.512	11.32	0.262	−0.152	1.099	0.023
Compatibility	0.178	0.473	0.032	0.496	10.601	0.246	0.457	10.007	0.209
Complexity	0.214	0.681	0.046	0.065	0.18	0.004	−0.476	10.837	0.226
Trialabliity	0.106	0.167	0.011	0.397	6.814	0.158	0.525	13.224	0.276
Observability	0.552	4.522	0.304	−0.024	0.026	0.001	0.100	0.482	0.010
Innovation	0.367	2.001	0.135	0.389	6.523	0.151	−0.581	16.170	0.338
Communication channels	0.563	4.714	0.317	−0.228	2.247	0.052	−0.085	0.345	0.007
Time	0.482	3.449	0.232	−0.218	2.050	0.047	−0.432	8.949	0.187
Social systems	0.731	7.942	0.535	−0.273	3.210	0.074	0.027	0.034	0.001
Context of application	0.600	5.345	0.360	0.465	9.345	0.217	−0.298	4.248	0.089

Note: 'Dim' and 'Ctr' in the table refer to dimension and contribution, respectively.

3.1.3. Topical Clusters Based on Factor Variables

Classification based on the observations revealed three clusters. Representation of the factor variables in each cluster was assessed using hypergeometric distribution[2]; the variables with significant *p*-values with their corresponding v-test value for each cluster are presented in Table 3. In all three clusters, '*social system*', '*social dimensions*', and '*informal communication*' appeared significant as the determining variables. '*Organizational diversity*' appeared significant in the first and third clusters, whereas '*compatibility*' and '*trialability*' appeared significant only in the first cluster.

Table 3. Significant variables contributing to three different clusters with their frequencies, *p*.value, and *v*.test.

Classification	Variables	Intern Freq.	Glob Freq.	*p*.Value	*v*.Test
Cluster 1	Compatibility	196	322	4.084051×10^{-03}	2.871596
	Trialabliity	187	313	1.584161×10^{-02}	2.412544
	Organizational diversity	79	177	2.885287×10^{-02}	−2.185491
	Social systems	34	132	2.252916×10^{-10}	−6.343029
	Informal communication	4	57	2.206909×10^{-13}	−7.335624
	Social dimension	6	98	1.608176×10^{-23}	−9.994673
Cluster 2	Social.dimension	53	98	4.779540×10^{-11}	6.577646
	Social systems	43	132	1.587664×10^{-02}	2.411739
	Informal communication	5	57	8.481098×10^{-03}	−2.632292
Cluster 3	Informal communication	48	57	1.196667×10^{-21}	9.558335
	Social systems	55	132	7.028043×10^{-06}	4.492837
	Social dimension	39	98	5.834247×10^{-04}	3.439205
	Organizational diversity	58	177	7.749489×10^{-03}	2.662794
	Disciplines	32	160	1.450073×10^{-02}	2.444614

Note: *v*.test (test value) corresponds to the transformation of *p*.value into the quantile of the normal distribution which indicates if the coordinate of the category significantly different to 0. If the *p*.value is less than 5%, the absolute value of the test value will be greater than 1.96. The sign (+ or −) of the test value indicates (greater or lower).

In cluster 1, research articles[3] (*15* and *94*) and the main characters of the groups were high for the factor variables '*context of application*', '*research priorities*', '*relative advantage*', '*knowledge*', '*problem-solving effort*', '*problem definition*', '*innovation*', '*observability*', '*compatibility*', and '*cognitive*' (variables sorted from the strongest) with low values for the factor variables '*disciplines*' and '*informal communication*' (variables sorted from the weakest). Research articles published by BJA fell under cluster 1 as the articles considered '*context of application*', '*research priorities*', '*relative advantage*', and '*problem-solving effort*'. Many of the research agendas in cluster 1 were prioritized based on the field problems. However, studies were conducted solely by researchers without the involvement of stakeholders from different disciplines and organizations. Thus, the exclusion of the stakeholders including end-users during the research process results in poor adoption of the technologies generated. The '*problem-solving effort*' of the research was a singular disciplinary approach that resulted in limited adoption of the findings due to complex field issues. A robust integrated (natural and social research) transdisciplinary framework has proven to address such complex field problems (Simon and Schiemer 2015).

Cluster 2 included articles *9*, *10*, *29*, and *56*. The group was characterized by low values for variables like '*Context of application*', '*problem solving effort*', '*research priorities*', '*problem definition*', '*relative advantage*', '*social dimension*', '*diffusion*', '*result diffusion*', '*social system*', and '*knowledge*' (variables are sorted from the weakest). The articles published were mainly oriented towards broadening the knowledge base without actually addressing societal issues. The articles were highly disciplinary and fall under traditional Mode 1 knowledge production. The majority of such journal articles were published by BJNRD. The articles were purely of academic interest, only broadening the knowledge horizon without focusing on solving prevailing societal problems. Such articles were low in contextual relevance as well as '*research priorities*' without practical application. Almost 50% of the articles included in this study fall under cluster 2. Low focus on '*social dimensions*' and lack of understanding were identified as the main hurdles for effective creativity and innovation (Luebke 2011).

Cluster 3 constituted articles *6*, *13*, *18*, *36*, *39*, *46*, *48*, *66*, and *67*. This group was characterized by high values for variables like '*disciplines*', '*organizational diversity*', '*informal' communication*, '*social system*', '*social dimension*', '*communication channel*', '*diffusion*', 'result *diffusion*', '*problem solving effort*', and '*time*' (variables were sorted from the strongest). Innovation attribute variables and innovation diffusion elements (except for social systems) were not considered by the articles in this cluster. Most of the Mode 2 knowledge production variables were considered by the articles in this cluster.

BJNRD journals tend to publish papers of disciplinary academic studies, while BJA shows a preference for papers with a practical problem-solving approach. However, the reductionist approach to research problems has impeded solving complex field issues.

The classification of three topical clusters based on the factors or variables is shown below in Figure 4.

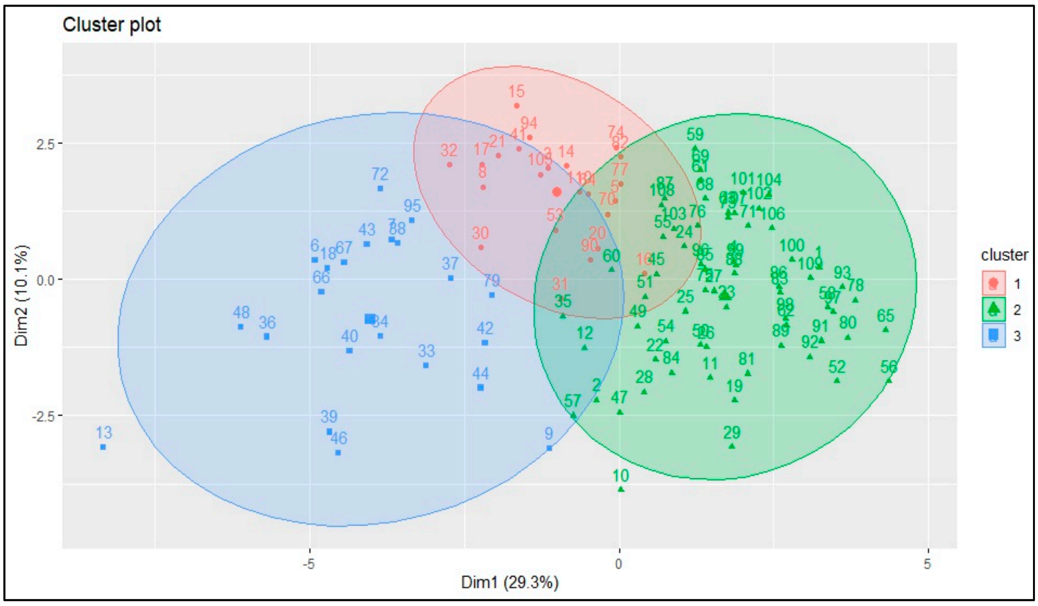

Figure 4. Ascending hierarchical classification of the articles, revealing 3 clusters. Each Roman numeral in the scatterplot indicates the article serial number.

3.2. *Findings from the Assessment Using Rogers Innovation Attributes*

Innovation dissemination can be studied from different structures and elements of the innovation system. A dearth of literature exists on how innovation adoption can be enhanced by including the knowledge production process. Previous studies have focused on Rogers innovation attributes as well as the adopter's personal characteristics for determining the adoption of innovation in a given context (Ostlund 1974). Socioeconomic characteristics such as financial well-being and personnel characteristics affect innovation adoption. Willingness to take risks, social integration, availability of funds, personal interests, self-confidence, ability to cope with problems, and level of education affect the adoption of an innovation as well (Sahin 2006). Thus, the technology generated is seldom consistent with adopter needs and capacities, while human and financial resources are limited (Christensen et al. 2012). In fact, the disconnect between research and extension and an obsolete linear research-extension approach can be reasonably viewed as what underpins poor adoption in the Bhutanese context.

Our assessment of perceived characteristics of innovation in terms of innovation attributes showed variable results. Overall, '*complexity*' received the highest score (about 62%), followed by '*compatibility*' (60%), among the five innovation attributes. The high score for the attribute '*complexity*' shows that much of the research conducted was complex, affecting adoption. The '*compatibility*' attribute fell within the '*Often*' adopted category. However, '*observability*' of the innovation had the lowest score (less than 40%), falling under attributes that are considered '*Often*'. The articles published in the Bhutanese journals considered, on average, four attributes (*relative advantage*, *compatibility*, *complexity*, and *trialability*), falling within the 'usually adopted' category range. The innovations generated as applied research to date were grounded on field problems, especially those published by the Bhutanese Journal of Agriculture and Renewable Natural Resource

(RNR). The attribute '*observability*' had the lowest score (less than 40%), indicating that the innovations generated were mainly of a 'process' or 'soft innovation'[4] type. Product innovation consisted of varietal evaluation research; these studies were published by RNR Journal and BJA. On-farm evaluation trials constituted about 20% of the research. Such innovation research, especially for perennial crops, remains visible for potential adopters. However, annual and seasonal crops remain in the field for a brief time, thus affecting their overall visibility. Unless researchers involve end-users via certain extension approaches such as field demonstration or on-farm trials, innovation rarely reaches target end-users due to observability.

The innovations (new crop varieties) that underwent rigorous evaluation procedures (on research stations and on-farm trials) and were released for growers remain minimally adopted due to poor '*observability*'. Especially for annual crops, to increase the visibility of the technology, many extension researchers in the past adopted the participatory evaluation technique, where technology is evaluated in the grower's field by involving stakeholders from different institutes (ARDC Bajo 2015; Bajgai et al. 2018). In addition, innovative ideas such as crop management practices, policy research, and socio-economic research remain poorly visible to potential adopters, which results in low '*observability*' and thus affects subsequent adoption. Such innovations usually have been transferred to the end-users either through training programs or through extension teaching and learning materials (leaflet, folders, pamphlets, bulletins, newspapers, magazines, journals, and newsletters). However, they have rarely reached the target end-users, as most Bhutanese farmers are illiterate. Further, the social dynamics of end-users as reported in the Bhutanese context appears to affect technology adoption (Dorji et al. 2016). To overcome the issue of the social dynamics of end-users, innovators and stakeholders engage in video-based advisory services for the effective dissemination of technologies with poor visibility. One such example is the preparation of 'bran Bokashi' and 'BioChar' preparation and application, currently available on YouTube (https://www.youtube.com/watch?v=sIQtSm17VmQ, accessed on 20 January 2021). In the recent past, a technology park concept was practiced by the Bhutan RNR extension centers to highlight both the soft and hard technology, but was later discontinued due to logistical issues.

3.3. Rogers Innovation Diffusion Elements and Bhutanese Agricultural Research

Innovation diffusion elements were used to determine the adoptability of innovation in a number of ways. The Rogers innovation decision process involves three key steps: knowledge production (process or products), communication (to persuade innovators), and decision-making by adopters. Out of the four diffusion elements studied, innovation (innovative ideas, process of products) had the highest score (50%) within the '*usually*' adopted category, followed by the '*communication*' element (40%). Both the '*innovation*' and '*communication channel*' elements fall under the '*often*' considered category among Bhutanese agriculture researchers. However, two elements ('*time*' and '*social system*') were the least considered, despite falling within the '*often*' adopted category. The innovations generated in the Bhutanese context remained minimally adopted due to a lack of consideration of the '*time*' and '*social system*' elements of innovation diffusion. The time lag occurs as the dissemination process requires a series of processes, from knowledge production, to the creation of awareness among potential adopters, to actual adoption decision-making (Aggarwal et al. 2019). Bringing on board all the relevant stakeholders from the beginning would shorten the time needed for the actual adoption decision.

Innovation attributes determine the time required for potential adopters to adopt a particular innovation. Innovations with high profitability and relative utility but that are less complex and risky tend to take a shorter time to adopt by potential adopters, while complex innovation requiring high capital investment diffuses at a slower rate (Batz et al. 2003). In fact, traditional innovation attributes were found to be insignificant for decision timelessness (Ciganek et al. 2014). Bhutanese innovators need to be mindful of the time factor as one of the important elements of diffusion. Often, technology that takes a long time for adoption is irrelevant and out-of-date in the ultimate adoption context. Many crop varieties were released almost two to three decades ago but only a few are currently in practice. The Bhutan Department of Agriculture has approved a total of 53 field crop varieties, 110 fruit cultivars, and 111 vegetable cultivars since 1988, of which nine, 27, and one, respectively, were recently de-notified (DoA Bhutan 2021).

Figure 5 shows the average score for the five different Rogers innovation attributes and innovation diffusion elements as considered by Bhutanese agricultural researchers.

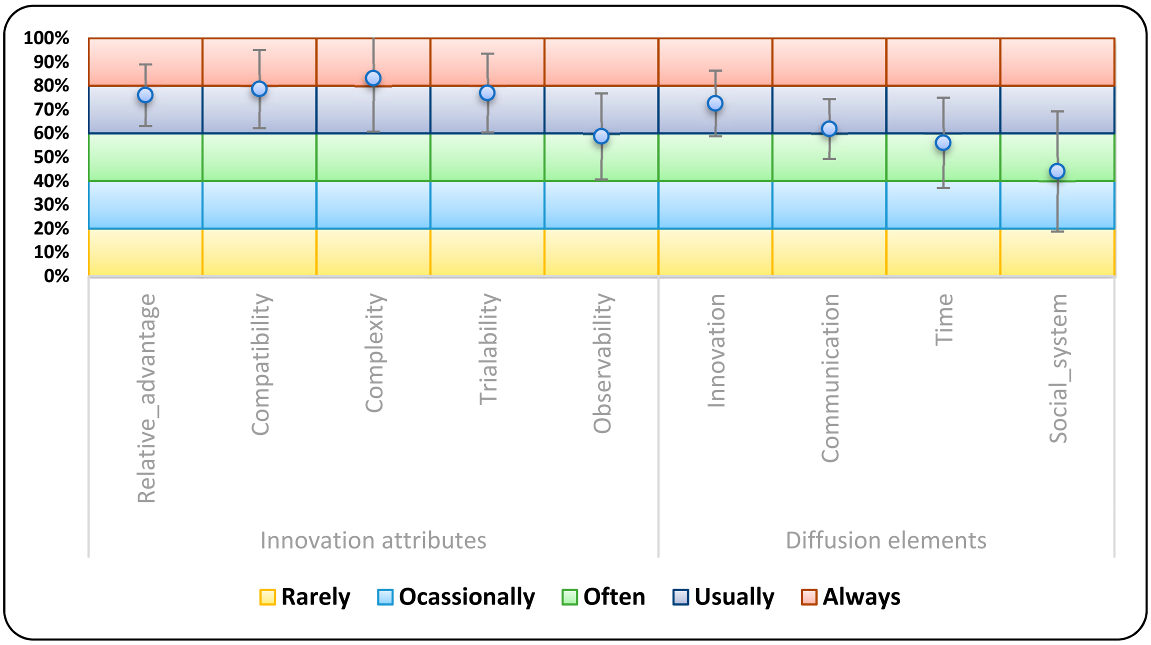

Figure 5. Rogers innovation attributes and diffusion element average scores: error bars depict the mean deviation from the average score.

3.4. An Assessment Using Mode 2 Knowledge Production Features

Public research institutes (PRI) and universities across the world are evolving knowledge production and its diffusion. This typical linear approach consists of two distinct phases in which research institutes first innovate and later work on the dissemination of the innovation (Cooksey 2011). In contrast, Mode 2 knowledge production process is a non-linear approach in which transdisciplinary and relevant stakeholders (innovators, end-user, policymakers, and communicators) team up to innovate and work on adoption simultaneously. Therefore, diffusion of the results occurs in the process of knowledge production. This type of Mode 2 knowledge production enables real-time evaluation (developmental evaluation) for adaptation and diffusion as it evolves in the context of the application (Patton 1994) while enhancing innovation relevance and adoption. Further, the Mode 2 knowledge production is characterized by a diverse range of quality controls (via reflexivity) while maintaining social accountability (Coghlan 2014).

Bhutanese researchers have adopted various levels of Mode 2 knowledge production and its variable factors. The '*context of application*' of innovation had the highest score (65%) in the 'usually' considered category (Figure 6). Under transdisciplinarity, Bhutanese researchers have considered '*problem-solving*' and '*knowledge*' aspects, as both fell within the range of the 'often' adopted category. In particular, research conducted by the agricultural institutions (BJA and RNR Journal) was mostly applied research. Thus, the context of application and problem-solving efforts appeared at the forefront of the research agenda. However, '*diffusion*' of the knowledge under transdisciplinarity received the lowest score, indicating that many Bhutanese researchers inadequately incorporated disciplinary pluralism. This is likely due to Bhutan following a linear systems research extension approach by which researchers generate technology and extension-disseminate it to potential adopters.

Further, under 'heterogeneity' category, both '*discipline*' and '*organization*' were within the 'often' considered category. This shows that the researchers remained confined to their disciplinary and organizational boundary. They rarely collaborated with experts from different organizations and disciplines. This exclusion of transdisciplinary specialists from diverse backgrounds and organizations affected the utility of the results. The transdisciplinarity paradigm has increasingly been assumed in the translation of knowledge, although transdisciplinary collaboration is a complex social process (Archibald et al. 2018).

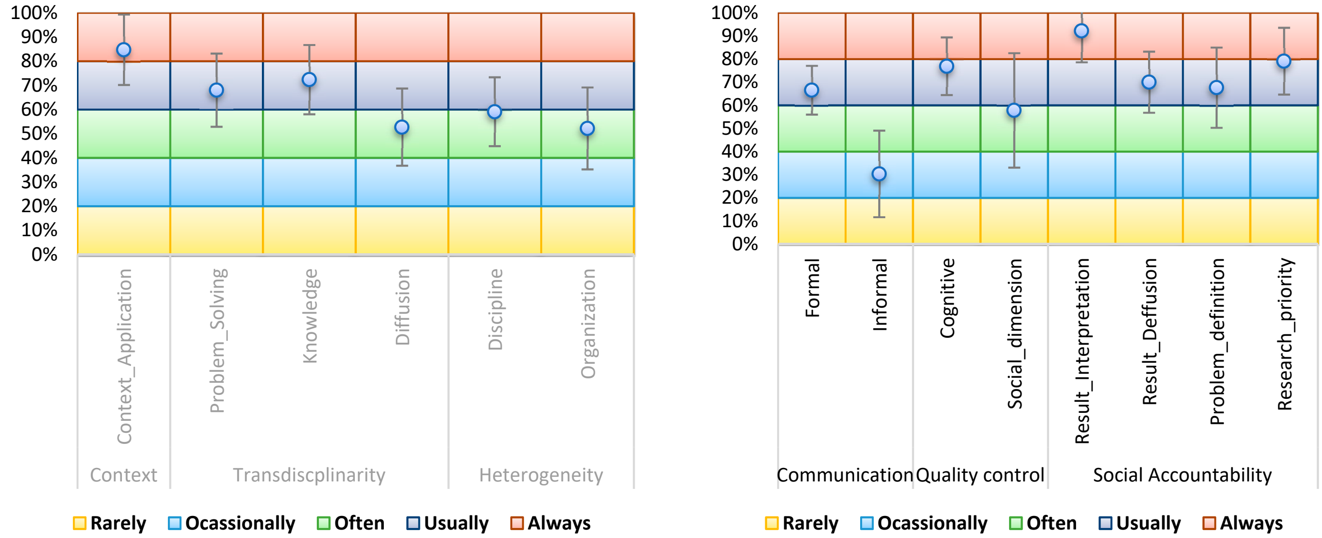

Figure 6. Mode 2 knowledge production features and variables with their corresponding scores with mean deviation from average score.

Adoption of innovation depends directly on the level and mode of communication. While '*formal*' communication in the form of journal publication was within the average range, Bhutanese researchers had least considered '*informal*' communication. Similarly, in quality control aspects, the '*cognitive*' component was adopted well, falling under the 'often' category. Social dimensions were also 'rarely' considered by the Bhutanese researchers. For social accountability, variables such as '*result interpretation*', '*result diffusion*', and '*problem definition*' fell within the 'often' adopted category. From our findings, the low adoption of the Bhutanese agricultural innovations was due to a low focus on social dimensions and poor informal communication. The weakness of the Bhutanese research policy and need for socio-economic aspects have been pointed out in the past as well (Christensen et al. 2012). Poor accountability in agricultural research and the need for socio-economic research along with the issue of knowledge management have been emphasized in the Bhutanese Agriculture research strategy 2018–2028 (ARED-DoA Bhutan 2021). However, Mode 2 knowledge production features, especially *transdisciplinarity*, *organizational diversity*, and social accountability, as well as fund support needs, have been inadequately mentioned.

4. Conclusions

Agriculture knowledge and innovation systems have significantly changed across the globe, but Bhutan's agriculture research and extension services still follow an old linear system of technology diffusion approach. Research institutions innovate, and extension service providers bring innovations to potential adopters. The government document 'Agriculture Research Strategy 2018–2028' clearly mentioned that the linear system of extension is likely to continue for the next ten years. Thus, the Bhutanese agriculture innovation system needs a paradigm shift in its policy and strategy to meet the changing needs of Bhutanese growers in the modern context with a robust system of innovation.

We found that PCA can be a useful tool in the analysis of data structures and for extracting information content from an ordinal dataset. Our study grouped the Bhutanese journal articles into three main clusters. Each cluster consisted of articles differing in their factor variable characteristics. The BJA and RNR Journal published contextualized research articles grounded on field issues, while BJNRD (Royal University of Bhutan) published academic-discipline-based research articles. The Bhutanese agricultural research have well considered innovation attributes, except for 'observability'. The poor visibility of Bhutanese agriculture research appears inherent to seasonal crop varieties, while soft preliminary and academic research remains invisible and unadoptable. At the same time, the articles published indicated that the complexity of the innovation research made it hard to comprehend and use.

Mode 2 knowledge production is an approach that produces knowledge in context while simultaneously evolving and being adopted in the process. The Mode 2 knowledge production features shed light on areas of current research limitations. Bhutanese research policy and strategy must incorporate these factors to enhance societal relevance and simultaneous adoption; pertinent issues identified in this study were 'informal' communication channels and 'social dimensions'.

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Notes

[1] A research budget allocation of 2% of agricultural GDP is considered as the norm.

[2] The number of times an event occurs in the fixed trials where each trial changes the probability of each subsequent as there is no replacement.

[3] The observation refers to the article explored and the roman number refers to the corresponding article serial number.

[4] Implementing a new or improved production method.

References

Abdi, Hervé, and Lynne J. Williams. 2010. Principal component analysis. *WIREs Computational Statistics* 2: 433–59. [CrossRef]

Aggarwal, Richie, Ompal Singh, Adarsh Anand, and P. K. Kapur. 2019. Modeling innovation adoption incorporating time lag between awareness and adoption process. *International Journal of System Assurance Engineering and Management* 10: 83–90. [CrossRef]

Alekseevna, Mikhaylova Anna. 2014. Evolution of the Innovation Process Models. *International Journal of Econometrics and Financial Management* 2: 119–23.

Alon, Adi, and Dan Elron. 2015. *Innovation: Clear Vision, Cloudy Execution*. Chicago: Accenture.

Andrews, Rhys, and Gene A. Brewer. 2013. Social Capital, Management Capacity and Public Service Performance. *Public Management Review* 15: 19–42. [CrossRef]

Archibald, Mandy M., Michael Lawless, Gillian Harvey, and Alison L. Kitson. 2018. Transdisciplinary research for impact: Protocol for a realist evaluation of the relationship between transdisciplinary research collaboration and knowledge translation. *BMJ Open* 8: e021775. [CrossRef] [PubMed]

ARDC Bajo. 2015. *Annual Report 2013–2014*; Bajo: Wangdue.

ARED-DoA Bhutan. 2021. *Agriculture Research Strategy 2018–2028*; Edited by Agriculture. Thimphu: RGoB.

Bajgai, Yadunath, Tshering Dochen, Pema Wangchuk, Mohinder S. Kadian, Thomas Z. Felde, Mathelde Lefebvre, Lobzang, Sushma Arya, Sangay, Tashi Wangdi, and et al. 2018. Participatory varietal selection of potato and agronomic performance with farmers' feedback on new varieties. *Bhutanese Journal of Agriculture* 1: 1–12.

Batz, Franz-J., Willem Janssen, and Kurt J. Peters. 2003. Predicting technology adoption to improve research priority—Setting. *Agricultural Economics* 28: 151–64. [CrossRef]

Bhutan National Council. 2014. *Review of Agriculture Policy by Natural Resources & Environment Committee (NREC)*; Thimphu: National Assembly of Bhutan.

Brinkerhoff, Derick W., and Arthur A. Goldsmith. 1992. Promoting the sustainability of development institutions: A framework for strategy. *World Development* 20: 369–83. [CrossRef]

Bro, Rasmus, and Age K. Smilde. 2014. Principal component analysis. *Analytical Methods* 6: 2812–31. [CrossRef]

Carayannis, Elias G., David F. J. Campbell, and Scheherazade S. Rehman. 2016. Mode 3 knowledge production: Systems and systems theory, clusters and networks. *Journal of Innovation and Entrepreneurship* 5: 17. [CrossRef]

Chor, Ka Ho Brian, Jennifer P. Wisdom, Su-Chin Serene Olin, Kimberly E. Hoagwood, and Sarah M. Horwitz. 2015. Measures for Predictors of Innovation Adoption. *Administration and Policy in Mental Health* 42: 545–73. [CrossRef] [PubMed]

Christensen, Garry Neil, Turi Filecci, and Aidan Gullivera. 2012. *Bhutan Agriculture Sector Review—Issues, Institutions and Policies*. Rome: FAO.

Ciganek, Andrew Paul, William Haseman, and K. Ramamurthy. 2014. Time to decision: The drivers of innovation adoption decisions. *Enterprise Information Systems* 8: 279–308. [CrossRef]

Coghlan, David. 2014. Mode 1 and Mode 2 Knowledge Production. In *The SAGE Encyclopedia of Action Research*. London: SAGE Publications Ltd., pp. 540–42. [CrossRef]

Cooksey, Ray W. 2011. Yours, Mine or Ours: What Counts as Innovation? *The Journal of Agricultural Education and Extension* 17: 283–95. [CrossRef]

Dearing, James W. 2009. Applying Diffusion of Innovation Theory to Intervention Development. *Research on Social Work Practice* 19: 503–18. [CrossRef] [PubMed]

DoA Bhutan. 2021. *Inventory of Released and De-notified Crops in Bhutan (1988–2021)*. Edited by Agriculture. Thimphu: RGoD.

Dorji, Kinley, Lakey Lakey, Sonam Chophel, Sonam Dechen Dorji, and Birkha Tamang. 2016. Adoption of improved citrus orchard management practices: A micro study from Drujegang growers, Dagana, Bhutan. *Agriculture & Food Security* 5: 3. [CrossRef]

FAO. 2018. *FAO's Work on Agricultural Innovation*. Rome: FAO.

Frost, Jetta, and Margit Osterloh. 2003. Dialogue Devices: Bridging Between "Mode 1" and "Mode 2" Knowledge Production. In *Communication in Organizations. Structures and Practices*. Frankfurt: Frankfurt a. M., pp. 81–101.

Gibbons, Michael, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Seot, and Martin Trow. 1994. The Dynamics of Science and Research in Contemporary Societies. In *The New Production of Knowledge*. London, Thousand Oaks and New Delhi: SAGE Publications.

Harkins, Arthur M., and George H. Kubik. 2006. Leapfrogging toward the "singularity": Innovative knowledge production on market-driven campuses. *On the Horizon* 14: 99–107. [CrossRef]

Hessels, Laurens K., and Harro van Lente. 2008. Re-thinking new knowledge production: A literature review and a research agenda. *Research Policy* 37: 740–60. [CrossRef]

Jolliffe, Ian T., and Jorge Cadima. 2016. Principal component analysis: A review and recent developments. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 374: 20150202. [CrossRef]

Kaiser, Henry F. 1960. The Application of Electronic Computers to Factor Analysis. *Educational and Psychological Measurement* 20: 141–51. [CrossRef]

Kapoor, Kawaljeet, Yogesh K. Dwivedi, and Michael D. Williams. 2013. Role of innovation attributes in explaining the adoption intention for the interbank mobile payment service in an Indian context. In *Grand Successes and Failures in IT. Public and Private Sectors. TDIT 2013. IFIP Advances in Information and Communication Technology*. Edited by Yogesh K. Dwivedi, Helle Zinner Henriksen, David Wastell and Rahul De'. Berlin and Heidelberg: Springer, vol. 402. [CrossRef]

Kapoor, Kawaljeet Kaur, Yogesh K. Dwivedi, and Michael D. Williams. 2014. Innovation adoption attributes: A review and synthesis of research findings. *European Journal of Innovation Management* 17: 327–48. [CrossRef]

Kassambara, Alboukadel. 2017. Principal Component Methods in R: Practical Guide. PCA—Principal Component Analysis Essentials. Available online: http://www.sthda.com/english/articles/31-principal-component-methods-in-r-practical-guide/112-pca-principal-component-analysis-essentials/#:~{}:text=Correlation%20circle&text=It%20shows%20the%20relationships%20between,plot%20origin%20(opposed%20quadrants (accessed on 15 January 2019).

Krishnan, Armin. 2009. *What Are Academic Disciplines? Some Observations on the Disciplinarity vs. Interdisciplinarity Debate*. Southampton: University of Southampton.

Kristian Häggman, Sami. 2009. Functional actors and perceptions of innovation attributes: Influence on innovation adoption. *European Journal of Innovation Management* 12: 386–407. [CrossRef]

Luebke, Roy. 2011. Impact of Social Factors on Innovation. Available online: https://www.disruptorleague.com/blog/2011/04/05/impact-of-social-factors-on-innovation (accessed on 22 January 2021).

Meijer, Seline S., Delia Catacutan, Oluyede C. Ajayi, Gudeta W. Sileshi, and Maarten Nieuwenhuis. 2015. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability* 13: 40–54. [CrossRef]

Mohr, John W., and Harrison C. White. 2008. How to Model an Institution. *Theory and Society* 37: 485–512. [CrossRef]

Neese, Brian. 2017. Cultivating a Robust Organization: 5 Stages of the Innovation Process. Available online: https://online.rivier.edu/5-stages-of-the-innovation-process/ (accessed on 19 August 2018).

Newig, Jens, Stephanie Jahn, Daniel J. Lang, Judith Kahle, and Matthias Bergmann. 2019. Linking modes of research to their scientific and societal outcomes. Evidence from 81 sustainability-oriented research projects. *Environmental Science & Policy* 101: 147–55. [CrossRef]

Nowotny, Helga, Peter Scott, and Michael Gibbons. 2003. Introduction: 'Mode 2' Revisited: The New Production of Knowledge. *Minerva* 41: 179–94. [CrossRef]

OECD. 1996. The Knowledge-Based Economy. Available online: https://www.oecd.org/sti/sci-tech/1913021.pdf (accessed on 26 September 2018).

Ostlund, Lyman. 1974. Perceived Innovation Attributes as Predictors of Innovativeness. *Journal of Consumer Research (pre-1986)* 1: 23. [CrossRef]

Patton, Michael Quinn. 1994. Developmental evaluation. *Evaluation Practice* 15: 311–19. [CrossRef]

R Core Team. 2014. *R: A Luanguage and Environment for Statistical Computing*. Vienna: R Foundation for Statistical Computing.

Rasmussen, Charlotte Diana Nørregaard, Helene Højberg, Elizabeth Bengtsen, and Marie Birk Jørgensen. 2018. Identifying knowledge gaps between practice and research for implementation components of sustainable interventions to improve the working environment—A rapid review. *Applied Ergonomics* 67: 178–92. [CrossRef]

Rogers, Everett M., Arvind Singhal, and Margaret M. Quinlan. 2014. Diffusion of innovations. In *An Integrated Approach to Communication Theory and Research*. London: Routledge, pp. 432–48.

Sahin, Ismail. 2006. Detailed review of Rogers' diffusion of innovations theory and educational technology-related studies based on Rogers' theory. *Turkish Online Journal of Educational Technology-TOJET* 5: 14–23.

Shrum, Wesley, and H. Malcolm Macdonald. 1985. From Knowledge to Wisdom: A Revolution in the Aims and Methods of Science. *Social Science Quarterly (University of Texas Press)* 66: 996–96.

Simon, David, and Friedrich Schiemer. 2015. Crossing boundaries: Complex systems, transdisciplinarity and applied impact agendas. *Current Opinion in Environmental Sustainability* 12: 6–11. [CrossRef]

Stockholm International Peace Research Institute. 2018. Trends in World Military Expenditure. Available online: https://www.sipri.org/sites/default/files/2018--04/sipri_fs_1805_milex_2017.pdf (accessed on 17 September 2018).

Taherdoost, Hamed. 2018. A review of technology acceptance and adoption models and theories. *Procedia Manufacturing* 22: 960–67. [CrossRef]

Tornatzky, Louis G., and Katherine J Klein. 1982. Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings. *IEEE Transactions on Engineering Management* 29: 28–45. [CrossRef]

Tress, Bärbel, Gunther Tress, and Gary Fry. 2005. Defining concepts and the process of knowledge production in integrative research. *From Landscape Research to Landscape Planning: Aspects of integration, Education and ApplicAtion* 12: 13–26.

Vaissie, Pauline, Astrid Monge, and Francois Husson. 2021. Perform Factorial Analysis from 'FactoMineR' with a Shiny. R Package Version 1.0. 6. Available online: https://cran.r-project.org/web/packages/Factoshiny/Factoshiny.pdf (accessed on 7 June 2022).

Van De Ven, Andrew H., and Paul E. Johnson. 2006. Knowledge for Theory and Practice. *Academy of Management Review* 31: 802–21. [CrossRef]

van der Hel, Sandra. 2016. New science for global sustainability? The institutionalisation of knowledge co-production in Future Earth. *Environmental Science & Policy* 61: 165–75. [CrossRef]

Vanclay, Frank M., A. Wendy Russell, and Julie Kimber. 2013. Enhancing innovation in agriculture at the policy level: The potential contribution of Technology Assessment. *Land Use Policy* 31: 406–11. [CrossRef]

Webb, Patrick, Gunhild Anker Stordalen, Sudhvir Singh, Ramani Wijesinha-Bettoni, Prakash Shetty, and Anna Lartey. 2018. Hunger and malnutrition in the 21st century. *BMJ* 361: k2238. [CrossRef]

Whalley, Alexander, and Justin Hicks. 2013. Spending Wisely? How Resources Affects Knowledge Production in Universities. *Economic Inquiry* 52: 35–55. [CrossRef]

Wisdom, Jennifer P., Ka Ho Brian Chor, Kimberly E. Hoagwood, and Sarah M. Horwitz. 2014. Innovation adoption: A review of theories and constructs. *Administration and Policy in Mental Health* 41: 480–502. [CrossRef]