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Innovation and technology in sustainable agriculture: Understanding farmers' drivers and barriers to adoption

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ABSTRACT

This study examines farmers' perceptions and understanding of adopting innovative and technology-based agricultural practices for sustainability. It identifies the main drivers and barriers influencing farmers' decisions to adopt technology, with the aim of encouraging farm-level research and promoting agricultural development. The study included 114 respondents and used a descriptive correlational research design. The findings show that farmers have a high level of understanding and positive attitudes toward technological innovation in agriculture. Key drivers of adoption include economic considerations, sociocultural factors, institutional support, and technological aspects. However, several major challenges limit adoption, including insufficient financial resources to purchase machinery, limited access to bank loans, and inadequate farm inputs such as land, quality seeds, mechanization, fertilizers, and pesticides. The results also indicate that years of farming experience are significantly related to economic factors. In addition, the type of agricultural mechanization and tools is significantly associated with technological aspects, while participation in training activities is significantly related to sociocultural and technological factors. Overall, the findings suggest that wider use of modern technology and machinery can be expected if these barriers are addressed.

1. Introduction

The everyday life of an individual is significantly influenced by agriculture, more so than they may have expected. More than 50% of human needs are fulfilled by agriculture, from the food people consume on their plates up to the Agri-money that fills their pockets (Kocira and Staniak, 2025).

Every nation that relies heavily on agriculture has sought to discover ways to develop the sector over the years. New methods of doing things are disseminated both inside and between agrarian communities through a process known as the "diffusion of agricultural innovations." Innovative agricultural technologies have developed to generate more resilient and sustainable agriculture. An illustration of this invention used in the Philippines is the WR8001 hand tractor, which can perform the tasks of ten workers simultaneously in a rice farm, and the F1 hybrid seed used in corn and papaya to ensure high-quality production (Chen and Li, 2022).

Due to its boundless rice-producing farms, Nueva Ecija is well-known for its rice fields and agricultural business, and as the "Rice Granary of the Philippines." Onion, mango, Calamansi, banana, garlic, and various vegetables are among the numerous crops grown in its fields. Cooperation across multiple organizations, cooperatives, and local government units increases agricultural production and simplifies farming. This public Adoption is significant in assisting farmers in overcoming adoption barriers and moving toward a more sustainable and resilient agriculture. Developing perspectives, making decisions, and acting occur between these endpoints in a dynamic, iterative manner. However, with self-adoption, all those innovations will be well-spent because innovation entails some uncertainty due to the variable number of possibilities and the wide range of relative probabilities of outcomes connected with the activities involved (Kalogiannidis et al., 2024).

Adoption is inevitable because change is constant. Innovation and adoption aim to improve people's quality of life. However, some individuals

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may find rapid and large-scale changes difficult to accept and follow.

Technology plays a key role in economic growth. Technology adoption and diffusion are closely related concepts. Adoption refers to the decision to use or not use a particular technology, while diffusion describes how that technology spreads over time across different sectors of the economy. Innovation adoption is not an immediate or single-step process; it takes time. Users may continue using a new technology or choose to discontinue it. The speed of adoption varies depending on the economic context, geographic location, and technical characteristics of the innovation. Therefore, understanding the technology adoption process and the time required for implementation is essential for designing effective agricultural research and extension programs.

Representing the agricultural sector, SEARCA Director Dr. Glenn B. Gregorio discussed the importance of ensuring food security and sustaining zero hunger beyond the global health crisis. He presented the Center's newly published paper, titled "Assessing the Impact of the COVID-19 Pandemic on Agriculture Production in Southeast Asia: Toward Transformative Change in Agricultural Food Systems." The paper highlights how disruptions in agricultural food systems create supply and demand shocks, which affect both short-term and long-term economic performance and food security.

The presentation also addressed the three components of the Emerging Innovation Group (EIG). The first component, Open Innovation and Agri-Incubation, emphasizes that advances in agricultural technology, combined with supportive policies and increased social awareness, are essential for transforming agricultural and rural development. The second component, Knowledge and Technology Transfer, focuses on developing and implementing intellectual property (IP) policies to ensure that products and technologies reach their intended beneficiaries. The third component, Project Development, Monitoring, and Evaluation, involves implementing larger and more strategic programs in collaboration with relevant partners to strengthen the organization's role as a leading facilitator of agricultural and rural development.

According to Rosário et al. (2022), the adoption of innovative and technology-based farming models has a significant positive effect on agricultural sustainability. In contrast, Campuzano et al. (2023) reported that many farmers face difficulties in adopting innovative approaches to sustainable agriculture due to the absence of effective policies that address their specific agricultural needs.

This paper contributes to the existing literature on the impact assessment of agricultural technologies. It examines the effectiveness of technology adoption in the production processes of local farmers in General Mamerto Natividad, Nueva Ecija. The aim is to encourage farmers to implement more advanced and sustainable agricultural practices on their farms.

This study aims to assess the level of farmers' understanding and perspectives regarding the adoption of innovative technologies in agriculture. Specifically, it first profiles the respondents based on key demographic and professional characteristics, including age, years of farming experience, educational level, and land tenure status. It also examines the types of agricultural machinery and tools currently used, as well as farmers' participation in organizations and training programs related to agricultural innovation and adaptation.

The study further identifies the main drivers influencing farmers' adoption of agricultural technologies, considering economic, socio-cultural, institutional, and technological factors that contribute to agricultural sustainability. In addition, it investigates the barriers that farmers encounter during the adoption process.

Finally, the research examines whether there is a significant relationship between the demographic and professional profiles of farmer-respondents and the factors that drive their adoption of innovative agricultural technologies. This comprehensive approach provides a holistic understanding of the technology adoption landscape and its implications for the agricultural community in the study area.

2. Methodology

The researchers employed a quantitative approach using a descriptive correlational research design. This design enabled them to collect numerical data, conduct appropriate statistical analyses, and draw objective conclusions. A descriptive correlational design was considered suitable for this study because it allows the researchers to assess the level of farmers' understanding regarding the adoption of innovative and technological machinery in sustainable agriculture and to examine the relationships among relevant variables.

The primary research instrument was a structured survey questionnaire. The questionnaire focused on farmers' understanding of innovative and technological machinery in sustainable agriculture and gathered data necessary to analyze the relationships among variables.

The respondents were informed about the nature and purpose of the survey research. Participation in the study was voluntary, and respondents were given the opportunity to decline involvement if they chose not to participate.

The respondents of the study consisted of 114 farmers from Barangay Panacsac, General Mamerto Natividad, Nueva Ecija. The researchers applied a total enumeration sampling method, in which all farmers in the barangay were included in the study, provided that they voluntarily agreed to participate.

The researchers employed a singular research instrument throughout the investigation. The researchers collected closed-ended answers using a standardized, self-administered questionnaire and compared the applicants based on the same

questions. They used a three-part questionnaire to obtain the essential information. Respondents asked questions about their demographics in Section 1. The profile tool used by the researchers determined the age, number of years as a farmer, and type of land ownership. They developed different questions for mediator elements such as the economic viewpoint, sociocultural component, institutional Factor, and technical aspect. The questionnaire consisted of 32 questions, and each question had four response options: strongly agree (4), agree (3), disagree (2), and strongly disagree (1). The creators of the questionnaire had farmers in mind and used appropriate vocabulary. The responses to each question were assessed using the Likert Scale, as indicated in Table 1.

Table 1: Likert scale interpretation used in the questionnaire

Response category	Scale value	Weighted mean range
Strongly agree	4	3.25 – 4.00
Agree	3	2.50 – 3.24
Disagree	2	1.75 – 2.49
Strongly disagree	1	1.00 – 1.74

2.1. Validity and reliability of data analysis

To ensure validity, the questionnaire was designed to reliably measure critical characteristics ranging from farmer profiles to adoption reasons and difficulties. The instrument's applicability was confirmed by a thorough literature review and a pilot study to refine questions.

To achieve reliability, a structured data gathering approach was used to reduce potential biases and provide consistent results. With Cronbach's Alpha of 0.73, it was determined that the questionnaire is acceptable. Together, these elements ensure that the study's findings are not only meaningful but also credible and reproducible. Together, these factors ensure that the study's findings are not only meaningful but also credible and reproducible. The Likert scales shown in Table 2 serve as a reference for interpreting the data collected.

3. Results and discussion

The profile of the respondents is shown below in terms of age, years as farmers, educational status, land ownership, type of agricultural mechanization and tools used in farming, farmer's organization group, and participation in any agricultural innovation and adaptation-related training activities of farmers. As shown in Table 3, the majority of farmers were aged 41-50 years, had farming experiences between 1 and 15 years, wherein most of them were high school level or high school graduate and they are the landowners.

Table 2: Interpretation of weighted mean scores for mediator variables

Weighted mean range	Scale value	Interpretation
3.25 – 4.00	4	Very high understanding of innovative and technological adaptation toward agricultural sustainability
2.50 – 3.24	3	High understanding of innovative and technological adaptation toward agricultural sustainability
1.75 – 2.49	2	Moderate understanding of innovative and technological adaptation toward agricultural sustainability
1.00 – 1.74	1	Poor understanding of innovative and technological adaptation toward agricultural sustainability

Table 3: Demographic profile of the respondents (N = 114)

Variable	Category	Frequency	Percentage
Age of farmers	30–40 years	26	22.81%
	41–50 years	40	35.09%
	51–60 years	26	22.81%
	61 years and above	22	19.30%
Years as a farmer	1–15 years	49	42.98%
	16–30 years	38	33.33%
	31–45 years	19	16.67%
	46–60 years	8	7.02%
Educational status	Elementary graduate	8	7.02%
	High school level	32	28.07%
	High school graduate	32	28.07%
	College level	10	8.77%
	College graduate	28	24.56%
Land ownership	Owner	78	68.42%
	Tenant	36	31.58%
Type of agricultural mechanization and tools used (multiple responses allowed)	Two-wheeled tractor and removable power tiller	62	54%
	Two-wheeled tractor-driven direct seed and fertilizer drill	58	51%
	Two-wheeled tractor single-row planter	56	49%
	Two-wheeled tractor-trailer for hauling produce	38	33%
	Self-propelled rice and wheat reaper	22	19%
	Happy seeder	22	19%
	Axial flow pump powered by a two-wheeled tractor	0	0%
	Small-scale sprayer cart	0	0%
Farmer organization membership	Yes	52	45.61%
	No	62	54.39%
Participation in training activities related to agricultural innovation and adaptation	Yes	60	52.63%
	No	54	47.37%

Almost half of the respondents reported owning a two-wheeled tractor, a removable power tiller, and a two-wheeled tractor-driven direct seed and fertilizer drill. This indicates their adoption of recent technological advancements and innovative practices in farming. In addition, many of them are members of farmers' organizations and actively participate in agricultural training programs to enhance their knowledge and promote sustainable agricultural development. The results also show that the majority of farmer-respondents have substantial farming experience. As landowners, they invest in machinery that improves farming operations, allowing for more efficient land preparation and increased productivity. Furthermore, they regularly attend training programs to increase their awareness of new farming methods, particularly those related to innovative and technology-based approaches to agricultural sustainability.

3.1. Farmers' drivers in the adoption of agricultural innovation

The factors affecting the adoption of agricultural innovation in General Mamerto Natividad, Nueva Ecija, are presented based on the corresponding weighted means of the farmers' responses. Table 4 shows the factors influencing adoption from an economic perspective. The overall weighted mean is 3.04, which is verbally interpreted as "Agree." This result indicates that farmers generally recognize the economic importance of adopting agricultural innovations. Among the given statements, the item "Adopting technology and innovation will yield better profit in agriculture" ranked first, with an average weighted mean of 3.30. This suggests that farmers strongly believe that technological adoption can improve their income. In contrast, the statement "The government provides sufficient financial support for improved technologies, devices, and machinery that result in abundant and high-quality agricultural products" received the lowest weighted mean of 2.65, although it was still verbally interpreted as "Agree." This indicates relatively lower agreement regarding the adequacy of government financial support. The results indicate that farmers demonstrate a high level of understanding of agricultural innovation from an economic perspective. They agree that adopting innovative technologies, such as hybrid seedlings, can lead to higher profits and help them compete with imported rice available in the market. Farmers also recognize that the adoption of agricultural technologies can increase their revenue by reducing operational costs.

Table 5 presents the data on sociocultural factors affecting the adoption of agricultural innovation. The overall weighted mean is 3.17, which is verbally interpreted as "Agree." Among the listed statements, "My family and I are always open to the possibility that new technologies could improve agriculture" received the highest average weighted mean of 3.40. In contrast, the statement "I applied technological innovation because it enhances the product's value" obtained the lowest weighted mean of 3.04, although it was still interpreted as "Agree." These findings suggest that sociocultural openness and family support play an important role in technology adoption among farmers.

Table 4: Economic perspective factors influencing the adoption of agricultural innovation (N = 114)

Statement	Weighted mean	Verbal interpretation
Adopting technology and innovation will yield better profits in agriculture.	3.30	Strongly agree
The government provides sufficient financial support for improved technologies, devices, and machinery that result in abundant and high-quality agricultural products.	2.65	Agree
I can afford new agricultural machines by earning income from using modern machinery and innovation.	2.79	Agree
I employ modern farming machinery and technological innovations to decrease operational expenses and increase income.	3.11	Agree
Given the current climate, I employ technological advancements to enhance the input-to-output process in agricultural production.	3.11	Agree
My profit or revenues have increased due to the application of technology in farming.	3.12	Agree
I use hybrid seedlings to compete with imported rice sold in the market.	3.25	Strongly agree
I implemented an innovation platform because the annual volume of products I sell increases, positively affecting crop production.	3.04	Agree
Overall mean	3.04	Agree

Table 5: Socio-cultural factors influencing the adoption of agricultural innovation (N = 114)

Statement	Weighted mean	Verbal interpretation
I applied technological innovation because it enhances the product's value.	3.02	Agree
My family, friends, and coworkers have influenced my perspective on modern farming.	3.11	Agree
I adapt well to using new technologies for farming.	3.07	Agree
I prefer modern farming machines and practices because they are less time-consuming.	3.33	Agree
My family and I are open to the possibility that new technologies could improve agriculture.	3.40	Agree
I am satisfied with the improvement of our agricultural industry.	3.07	Agree
We farmers have witnessed how technology and new ideas assist in resolving farming issues.	3.30	Agree
I use more advanced technology to reduce production challenges.	3.04	Agree
Overall mean	3.17	Agree

The study found that farmers have a high level of understanding of innovative and technological adaptation in relation to socio-cultural factors and agricultural sustainability. They agree that adopting innovative and technology-based practices can help address current farming challenges and improve

crop production. The farmer-respondents also demonstrate a strong understanding that technological advancements reduce the time required for farm preparation, improve the quality of work, and enhance overall agricultural productivity.

Dimitrijević (2023) stated that the adoption of technology in agriculture is essential for improving farm productivity. However, existing literature shows that the adoption rate of externally promoted technologies remains low, and the pace of adoption is often slow, particularly among small-scale farmers. Table 6 presents the data on institutional factors influencing the adoption of agricultural innovation. The overall weighted mean is 2.95, which is verbally interpreted as "Agree." Among the statements provided, "As farmers, we recognize that farming requires the adoption of new technologies and equipment" ranked highest, with an average weighted mean of 3.19. In contrast, the statement "The government's funding and assistance are sufficient for our regular agricultural activities" received the lowest weighted mean of 2.51. Although both statements fall under the verbal interpretation of "Agree," the lower mean score indicates relatively weaker agreement regarding the adequacy of government support.

Table 6: Institutional factors influencing the adoption of agricultural innovation (N = 114)

Statement	Weighted mean	Verbal interpretation
My agricultural land location makes it easier to use technology in cultivation.	3.00	Agree
Government efforts focus on attracting investors for innovative technology adoption.	3.02	Agree
Sufficient technological equipment makes adaptation easier to improve product quality.	3.07	Agree
Government funding and assistance are sufficient for regular agricultural activities.	2.51	Agree
Ongoing agricultural reforms influence my viewpoint on applying technology.	3.00	Agree
I can use technology in farming because the government provides enough assistance.	2.63	Agree
Farming requires the adoption of innovative technologies and equipment.	3.19	Agree
The government can adopt modern technologies and innovations for farmers.	3.18	Agree
Overall mean	2.95	Agree

The findings indicate that farmers demonstrate a high level of understanding of the role of institutional factors in the adoption of agricultural technology and innovation. The study shows that institutions significantly influence the uptake of agricultural technologies. In particular, government policies and agricultural extension services affect the adoption process and can either facilitate or limit technology use. Yokamo (2020) and Melesse (2018) argued that extension services play an important role in helping farmers adopt modern agricultural technologies. Through extension programs, farmers gain knowledge and skills related to new technologies. These services, therefore, contribute significantly to technology adoption. Furthermore, supportive government policies can promote the use of agricultural innovations. For example, policies related to automation, improved seed varieties, and precision farming can encourage both innovation and adoption.

Table 7 presents the data on technological factors affecting the adoption of innovative and technology-based agricultural sustainability. The technological aspect obtained an overall weighted mean of 3.15, which is verbally interpreted as "Agree." Among the statements provided, "I am aware of the new technological innovations in farming" ranked first, with an average weighted mean of 3.40 and a verbal interpretation of "Strongly Agree." In contrast, the statement "With the adoption of agricultural technology and innovation, we will be able to meet customers' new preferences and expectations" received the lowest weighted mean of 2.98, although it was still interpreted as "Agree."

Table 7: Technological factors influencing the adoption of agricultural innovation (N = 114)

Statement	Weighted mean	Verbal interpretation
I am aware of new technological innovations in farming.	3.40	Strongly agree
Technology adoption helps meet customers' new preferences and expectations.	2.98	Agree
I use new machinery because machines work longer and reduce labor costs.	3.23	Agree
Innovation and new technology positively impact my production activities.	3.21	Agree
I find it easy to adopt new agricultural innovations.	3.11	Agree
Technological advancements have increased the quality of my output.	3.25	Strongly agree
I use technology and machines to enhance my welfare.	3.12	Agree
Technological advancements reduce pesticide and fertilizer use.	3.12	Agree
Overall mean	3.15	Agree

The findings revealed that they agreed, and with a high level of understanding that the adoption of technological aspects can help them to meet agricultural needs using new advancement of machinery. They understand and perceive that technological aspects in agriculture have a positive impact on production activity and increase the quality of agricultural products.

Yokamo (2020) argued that some technologies are too complex for farmers to use easily. When a technology is divisible, such as high-yielding varieties, fertilizers, herbicides, or pesticides, farmers can test it on a small scale before fully adopting it. This opportunity for trial may increase their willingness to adopt the technology. In contrast, if a technology is indivisible (lumpy), farmers cannot test it gradually, which may reduce their willingness to adopt it. Yokamo (2020) also stated that farmers are more likely to adopt a technology when they consider it a good investment and suitable for their needs and local conditions. Furthermore, the effective performance of new

technologies and innovations significantly influences farmers' perceptions and adoption decisions.

3.2. Barriers faced by farmers in adopting agricultural technology and innovation

The barriers faced by farmers in adopting agricultural technology and innovation are presented through frequency, percentage, and rank distribution. Table 8 shows the major challenges encountered by farmers in the adoption process. The most significant barrier is insufficient budget to purchase advanced technologies and machinery, reported by 104 farmers (91%). In addition, 94 respondents (82%) identified limited access to bank loans as a major constraint. Furthermore, 68 farmers (60%) reported inadequate farm inputs—such as land, quality seeds, mechanization, fertilizers, and pesticides—as well as high input costs. They also noted a lack of space and storage facilities for harvested crops, machinery, and technological equipment. Other challenges include poor farm-to-market roads, lack of computerized machinery, and limited technical knowledge, which were reported by 42 respondents (37%). Poor information and communication technology (ICT) connectivity was identified by 58 farmers (51%). Additionally, 46 respondents (40%) reported inefficiencies in farming technologies and machinery due to harsh weather conditions. Finally, 56 farmers (49%) indicated that inadequate skills in operating new machinery and technologies remain a significant barrier to adoption.

Table 8: Barriers faced by farmers in adopting agricultural technology and innovation (N = 114)

Rank	Barrier	Frequency	Percentage
1	Insufficient budget to purchase advanced technology and machinery	104	91%
2	Lack of access to bank loans	94	82%
3	Inadequate farm inputs (land, seeds, mechanization, fertilizers, and pesticides)	68	60%
3	High expenses for inputs such as fertilizers, seeds, and machinery	68	60%
3	Lack of space and storage for harvested crops and machinery	68	60%
4	Poor information and communication technology connectivity	58	51%
5	Inadequate skills in operating new machinery and technology	56	49%
6	Inefficient farming technology due to harsh weather conditions	46	40%
7	Poor farm-to-market roads	42	37%
7	Lack of computerized machinery	42	37%
7	Lack of technical knowledge	42	37%

The results depicted that farmers were challenged to adopt agricultural technology and innovation because they have limited budgets, a lack of bank loan access, and inadequate farm inputs to provide agricultural technology and innovations, even if they have a high level of understanding that advanced machinery helps them to improve their agricultural productivity and output.

3.3. Relationship between farmers' profiles and technology adoption factors

Table 9 presents the data on the significant relationships between the profile of farmers and factors affecting the adoption of innovation and technology in agricultural sustainability. As shown, years as farmers r = 0.122 had a significant relationship on the economic perspective of farmers. This meant that the more years of experience in farming, the better their understanding of the adoption of innovative technology in agriculture. They tend to use technology in agriculture as perceived to have better crop production and outcomes. Furthermore, the type of agricultural mechanization and tools used by farmers was found to have a significant relationship with the technological aspect of adoption (r = 0.167). The results indicate that farmers who own and use more advanced agricultural machinery tend to demonstrate a better understanding of technological factors related to innovation adoption. In addition, participation in training activities showed a significant relationship with both socio-cultural factors (r = 0.167) and the technological aspect (r = 0.155). The findings suggest that farmers who attend training programs on advanced agricultural technologies exhibit stronger socio-cultural support for innovation and a better understanding of technical aspects of technology adoption.

Table 9: Correlation between the profile of farmers and factors affecting adoption of innovative technology in agricultural sustainability

Profile of farmers	Economic perspective	Socio-cultural factors	Institutional factors	Technological aspect
Age	-0.007	0.078	0.014	-0.041
Years as farmers	-0.122*	-0.085	-0.045	0.008
Educational status	0.048	-0.006	0.046	-0.007
Land ownership	-0.033	0.046	-0.013	-0.060
Type of agricultural mechanization and tools	0.008	0.094	0.025	0.167**
Farmer's organizational group	-0.055	-0.058	-0.081	-0.051
Participation in training activities	0.025	0.167**	0.025	-0.155**
N	114	114	114	114

*: Correlation is significant at the 0.05 level (2-tailed); **: Correlation is significant at the 0.01 level (2-tailed)

4. Conclusion

Based on the findings of the study, several conclusions can be drawn. The majority of farmers are between 41 and 50 years old, have sufficient farming experience, and are landowners. Almost half of them own two-wheeled tractors, removable power tillers, and two-wheeled tractor-driven direct seed and fertilizer drills. This indicates that they have adopted recent agricultural innovations and technological advancements. In addition, most farmers are members of agricultural organizations and actively participate in training programs to enhance their knowledge and promote agricultural sustainability and development.

The farmer-respondents demonstrate a high level of understanding and positive perceptions regarding the adoption of innovative agricultural technologies from economic, socio-cultural, institutional, and technological perspectives. However, farmers in General Mamerto Natividad face significant challenges in adopting agricultural technologies and innovations. The most common barriers include insufficient budget to purchase advanced machinery, limited access to bank loans, and inadequate farm inputs necessary to support technological improvement.

The results further indicate that years of farming experience are significantly related to the economic perspective of technology adoption. The type of agricultural mechanization and tools used is significantly associated with the technological aspect. In addition, participation in training activities shows a significant relationship with both socio-cultural and technological aspects of adoption.

The findings suggest the need to develop policies and programs that address the identified barriers and the significant relationships among variables influencing the adoption of new technologies and innovations for agricultural sustainability. Financial support programs should be strengthened to provide affordable credit and improve farmers' access to loans. Moreover, training and educational programs should be expanded to enhance farmers' understanding of the benefits and proper use of emerging agricultural technologies, thereby supporting long-term agricultural sustainability.

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Compliance with ethical standards

Ethical considerations

The study was conducted in accordance with ethical standards. All participants gave informed consent before participation, and their privacy and confidentiality were protected throughout the study.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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