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Comparative Analysis of Chilli Farming Systems: A Decomposition and Partial Budgeting Approach in Andhra Pradesh, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This study assesses the economic and productivity impacts of three chilli farming models—contract farming, Farmer Producer Organizations (FPOs), and traditional non-contract farming—in selected districts of Andhra Pradesh, India. A sample of 135 farmers was analyzed using partial budgeting and decomposition analysis. Results showed that FPO farmers achieved the highest net income and yield, followed by contract farmers, while non-contract farmers lagged behind. Partial budgeting revealed net gains of ₹5,147.10/ha for contract farmers and ₹28,197.13/ha for FPO farmers over non-contract farmers. Decomposition analysis indicated yield advantages of 23.17% for contract and 36.57% for FPO farmers, primarily driven by technological improvements rather than increased input use. These findings highlight the significant benefits of organized farming

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systems, especially FPOs, in boosting chilli productivity and profitability. Promoting such models can strengthen the economic resilience of smallholder chilli farmers and enhance sustainable agricultural practices in India. This can be achieved by strengthening institutional support for FPOs through access to credit, training, and collective marketing; encouraging fair and transparent contract farming arrangements with assured price mechanisms; improving extension services to disseminate advanced technologies; and fostering public–private partnerships.

Keywords: Contract farmers; decomposition; FPO farmers; non-contract farmers; partial budgeting.

1. INTRODUCTION

The Indian agricultural landscape has witnessed a significant transformation in recent decades, with a shift towards commercialization, particularly in high-value crops such as chillies. Chilli (*Capsicum* spp.) is a vital cash crop grown extensively for its economic and culinary importance. India is the world’s largest producer and exporter of dried chillies, with Andhra Pradesh accounting for over 30% of national production (FAOSTAT, 2023). Despite its economic potential, chilli cultivation remains highly vulnerable to fluctuations in input costs, market prices, and production risks, especially for smallholder farmers.

In response to these challenges, contract farming and Farmer Producer Organizations (FPOs) have emerged as viable institutional innovations aimed at improving farmer access to technology, credit, and markets. Contract farming facilitates a forward linkage between farmers and agribusiness firms by providing assured markets and input support (Barrett et al., 2021). Similarly, FPOs are collective enterprises that strengthen smallholders' bargaining power, enhance access to quality inputs, and reduce transaction costs through economies of scale (Trebbin, 2014).

Although the theoretical benefits of these models are well-established, empirical assessments of their comparative performance—particularly in terms of economic returns and productivity in chilli farming—remain limited. To bridge this gap, the current study evaluates the economic viability of contract and FPO farming models vis-à-vis traditional non-contract farming using partial budgeting analysis, which is a practical tool for assessing incremental changes in farm costs and benefits (Kay et al., 2016).

In addition, the study applies decomposition analysis based on the Cobb-Douglas production function to disentangle the observed yield differences between adopters and non-adopters into components attributable to technological effects and input use variations. This dual approach allows for a deeper understanding of how institutional innovations influence farm productivity and profitability in chilli cultivation.

By focusing on chilli farming in Andhra Pradesh—a leading chilli-producing region—this study provides policy-relevant insights into the role of organized farming systems in enhancing the livelihood outcomes of smallholders engaged in high-value agriculture.

2. MATERIALS AND METHODS

For the present study, three districts of Andhra Pradesh—NTR, Prakasam, and Kurnool—were purposively selected, as together they represent the three major chilli cultivation systems: contract farming, non-contract farming, and Farmer Producer Organization (FPO) farming. Within each district, three villages were identified to capture the diversity in production practices and institutional arrangements. Accordingly, Ramireddypalli, Jonnalagada, and Peddavaram/ Cherukumpalem were selected from NTR district; Vengalareddypalli, Jayaramapuram, and Yerragondapalem from Prakasam district; and Ralladoddi, Kadimetla, and Sugur from Kurnool district, making a total of nine villages. From these villages, a sample of 135 farmers was selected using a random sampling technique to ensure unbiased representation of the farming population. The sample comprised 45 contract farmers, 45 non-contract farmers, and 45 FPO farmers, with 15 farmers drawn from each village. The choice of 15 farmers per village was made to maintain uniform representation across locations and farming systems, while keeping the sample size statistically manageable for in-depth analysis. This approach ensured comparability across groups and enhanced the reliability of the study findings.

Chart 1. Partial budgeting technique

Debit(A)	Credit(B)
Added cost	Added returns
----------------------------Rs-------------------------------------	----------------------------Rs-------------------------------------
----------------------------Rs-------------------------------------	----------------------------Rs-------------------------------------
Reduced revenue	Reduced cost
----------------------------Rs-------------------------------------	----------------------------Rs-------------------------------------
----------------------------Rs-------------------------------------	----------------------------Rs-------------------------------------
Total added cost and reduced return(A) Rs---------------------	Total added returns and reduced cost(B) Rs---------------------
Net gain=B-A	

2.1 Partial Budgeting

The net incremental benefit of adopting contract or FPO cultivation was calculated using the following method. A partial budgeting analysis was conducted to assess the economic impact of adopting contract or FPO cultivation for chillies. This analysis aimed to determine whether contract farming or FPO farming for chillies is economically feasible for farmers.

Partial budgeting analysis, a simplified form of "marginal analysis," evaluates changes in costs and revenues resulting from a marginal change in cultivation practices. The net increment from adopting contract or FPO farming for chillies was calculated using the following method.

Chart 1 shows the partial budgeting technique was used to estimate the net gained due to the adoption of contract or FPO cultivation of chilliest by Sembiring, et al (2022).

2.2 Decomposition Analysis

Decomposition analysis was used to estimate the contribution of various resources to the outcome difference between beneficiary and non-beneficiary farmers. The outcome difference resulted by adoption of contract farming or FPO farming between the beneficiary and non-beneficiary farmer's production was decomposed into its constituent sources.

2.3 Step Wise Procedure

Step-1

Enter the data in excel

Step-2

Run cobb-douglas production function

=ln (select data)

Step-3

Run regression

Run all the three steps for beneficiary and non-beneficiary farmers data

Step-4

Analysis

$$\text{Ln } y1 = \ln b01 + b11 \ln x11 + b21 \ln x21 + \ldots\ldots\ldots + bn1 \ln xn1 + ui1 \quad (1)$$

$$\text{Ln } y2 = \ln b02 + b12 \ln x12 + b22 \ln x22 + \ldots\ldots\ldots + bn2 \ln xn2 + ui2 \quad (2)$$

Now, this is the formula for which we have to run decomposition analysis

$$\ln (y1)/ y2) = \{\ln (bo1 / bo2\} + \{(b11 - b12) \ln x12 + (b21 - b22) \ln x22 + \ldots\ldots\ldots\ldots + (bn1 - bn2) \ln xn2\} + \{b11 \ln (x11/ x12 + b21 \ln (x21/ x22) + \ldots\ldots\ldots + bn1 \ln (xn1/ xn2)\} + ui1 - ui2 \quad (3)$$

Ln y1=gross returns(y1) = gross returns of beneficiary (contract or fpo) farmers
Lny2= gross returns(y2) = gross returns of non-beneficiary (noncontract) farmers
Bo1=intercept value of beneficiary farmers
Bo2= intercept value of non- beneficiary farmers
B11…..bn1, b12….bn2 = co-efficient values of independent variables
Ui1, ui2 =error term

(i) ln (y1/y2) = ln (gross returns of beneficiary farmers / gross returns of non-beneficiary farmers)

   (a) then carryout [=average (num 1;num n)] average for ln (y1/y2)
   (b) for average of ln (y1/y2) carryout percentage

- This percentage is considered as output percentage.

(ii) ln(bo1/bo2) = ln (intercept value of beneficiary farmers / intercept value of non-beneficiary farmers)

- This percentage is called as neutral component.

(iii) ln x12*(b11-b12) = ln (sowing of non-beneficiary farmers(x12)) *(coefficient of sowing of beneficiary farmers(b11) - coefficient of sowing of non-beneficiary farmers(b12))

a) Then carryout [=average (num 1; num n)] average for [ln (sowing of non-beneficiary farmers(x12)) *(coefficient of sowing of beneficiary farmers(b11) - coefficient of sowing of non-beneficiary farmers(b12))

- Carryout same calculation for all variables, same as done in step-3 *i.e.,* ln x21*(b21-b22)

+……+ln xn1*(bn1-bn2).

(c) then carryout average for ln x12*(b11-b12), in the same way carryout average for all

(d) carryout =sum (ln x12*(b11-b12); x1n(bn1-bn2)) and then do percentage

- This percentage is considered as non-neutral component.

Step-5

(i) b11 ln (x11/ x12) = (co-efficient of sowing of beneficiary farmers(b11)) *ln (sowing of beneficiary farmers(x11)/sowing of non-beneficiary farmers(x12))

(a) then carryout average [=average (number 1; number n)] for b11* ln (x11/ x12) …. B1n*ln

(xn1/xn2) and then carryout percentage.

(b) carryout =sum (b11 ln (x11/ x12); b1n ln (xn1/xn2)), carryout percentage.

- This percentage is called as input percentage.

Step-6

- Calculate the difference between output percentage and input percentage.

Interpretation:

the decomposition analysis showed that the per hectare returns of beneficiary farmers was

x per cent higher than that of non-beneficiary farmers.

- Calculate the difference between neutral and non-neutral component.

Interpretation:

Technical change affects the output by shifting either intercept or the slope coefficients, or both. Technical changes divided into neutral technical and non-neutral technical changes. This revealed a x per cent contribution in the scale parameter (i.e., neutral technical change) and a y per cent contribution from the slope parameters (i.e., non-neutral technical change).

3. RESULTS AND DISCUSSION

3.1 Cost of Cultivation and Returns from Chilies Cultivation

Cost of cultivation of chillies was estimated separately for contract, FPO and noncontract farmers. The details of costs and returns of chillies are presented and discussed in this section.

3.2 Returns from Chillies Cultivation

The total costs and returns of contract/FPO and non contract cultivation of chilli are provided in Table 1.

The yield under FPO farming was 45.24 quintals per hectare, which was higher compared to both contract farming (44.57 quintals/ha) and non-contract farming (44.29 quintals/ha). However, the chilli produced through FPO and contract farming was of higher quality than that from non-contract farming. As a result, the price received by FPO and contract farmers was marginally higher at Rs. 17,089 per quintal, compared to Rs. 16,867 per quintal for contract farmers and Rs. 16,844 per quintal for non-contract farmers.

The Benefit-Cost Ratio (BCR) for FPO farming was 1.94, which was higher than that of contract farming (1.82) and non-contract farming (1.76).

Table 1. Costs and returns in chilli cultivation

(Rs./hectare)

S. No	Particulars	Contractfarming	Non contract farming	FPO farming
1	Total cost of cultivation/ha	414167	424167	398333
2.	Quantity produced quintal per ha	44.57	44.29	45.24
3.	Price received per quintal	16867	16844	17089
4.	Gross income	751762.19	746020.76	773106.36
5.	Net income (F-C)	337595.19	321853.76	374773.36
6	BCR (4/1)	1.82	1.76	1.94

Birthal et al. (2006) reported that contract dairy farmers earned 70% higher profits compared to non-contract farmers. Similarly, in potato cultivation, Kumar (2006) observed a 143% increase in profit for contract farmers over non-contract farmers. Similar results were reported by Untari et al. (2022) and Patel et al. (2014).

3.3 Net Gain from Adoption of FPO Farming or Contract Farming in Chillies

Partial budgeting is a planning and decision-making framework used to compare the costs and benefits of different alternatives faced by a farm business. It focuses solely on the changes in income and expenses that would result from implementing a specific alternative.

Partial budgeting includes a statement of added costs and added returns, arising from changes in one or a few farm activities—such as increasing or decreasing the level of an existing enterprise, or introducing a new enterprise.

The results of the partial budgeting analysis for contract and non-contract chilli farming are presented in Table 2.

Chilli cultivation under contract farming yielded an additional income of Rs. 5,147.10 per hectare compared to non-contract farming. Similar findings were reported by Sowjanya & Vijaya Kumari (2017) and Raja et al. (2021).

The results of the partial budgeting analysis for FPO and non-contract farming of chillies are presented in the Table 3. The cultivation of chillies with FPO farming had given an additional income of Rs. 28,197.13 per hectare compared to non-contract farming in chillies. Sembiring, A et al (2022)

Table 2. Evaluation of contract farming using partial budgeting technique

Sl.No.	Debit (A)		Credit (B)	
	Added cost	**Rs.**	**Added returns**	**Rs.**
1	Weeding (Rs/Ha)	200.89	Gross return	5741.43
2	Plant protection (Rs/Ha)	887.56	(Difference between thegross return of	
3	Fertilizers (Rs/Ha)	228.00	contract and non contract of chilli per	
4	Wages (Rs/Ha)	895.22	ha)	
5	Total Added Cost	2211.67		
6	Reduced revenue		Reduced cost	
7	-	-	Nursery and planting / sowing (Rs/Ha)	461.78
8	-	-	Staking, transport & other expenses (Rs/Ha)	1155.56
	(A) Total added cost and reduced return	2211.67	(B) Total added returnsand reduced cost	7358.77
	Net gain = B-A = 7358.77- 2211.67 = 5147.10			

Table 3. Evaluation of FPO farming using partial budgeting technique

Sl.No.	Debit (A)		Credit (B)	
	Added cost	**Rs.**	**Added returns**	**Rs.**
1	Weeding (Rs/Ha)	559.56	Gross return	27,085.60
2	Plant protection (Rs/Ha)	276.67	(Difference between thegross	
3	Fertilizers (Rs/Ha)	257.78	return of contract and non contract	
4	Wages (Rs/Ha)	1023.89	of chilli per ha)	

Sl.No.	Debit (A)		Credit (B)	
	Added cost	Rs.	Added returns	Rs.
5	Total Added Cost	2117.89		
6	Reduced revenue		Reduced cost	
7	-	-	Nursery and planting / sowing (Rs/Ha)	507.20
8	-	-	Staking, transport & other expenses (Rs/Ha)	2722.22
	(A) Total added cost and reduced return Net gain = B-A = 30315.02-2117.89 = 28,197.13	2117.89	(B) Total added returnsand reduced cost	30,315.02

3.4 Response Functions for Analysing the Yield Difference of Contract or FPO and Noncontract Chilli Farms

The impact of contract farming on the yield of chilli crops was estimated using decomposition analysis, and the results are presented in Table 4. The findings revealed that farmers who adopted contract farming achieved a per-hectare yield that was 23.17 percent higher than that of non-contract farmers. Technical modifications were categorized into neutral and non-neutral changes. Neutral changes indicate uniform shifts in productivity across all inputs (scale effect), while non-neutral changes reflect variations in the efficiency of specific inputs (slope effect). The contribution of the neutral component of the scale parameter was –1630.03 percent, while the contribution of the non-neutral component of the slope parameter was 1647.87 percent. The results show that the yield advantage of contract farmers is primarily due to non-neutral changes, i.e., better input use efficiency, rather than uniform productivity gains.

It was estimated that out of the 23.17 percent increase in yield among adopters, 17.84 percent could be attributed directly to the adoption of contract farming. This suggests that yields could be improved by 17.84 percent without any additional input usage.

The overall yield difference due to variations in input use between the two groups was calculated to be 5.34 percent. Among the inputs, expenditure on labour wages and nursery and planting/sowing contributed 4.17 percent and 0.02 percent, respectively, to the higher yields of adopters compared to non-adopters. This indicates that farmers under contract farming gained higher returns by investing more in labour and nursery operations.

However, the cost incurred for weeding contributed negatively to yield in adopter farms (–0.33 percent). Increased weeding expenditure in non-adopter farms contributed to a 0.33 percent higher yield in those farms. Similarly, other factors such as plant protection expenses (–1.25 percent), staking, transportation, and other miscellaneous expenses (–1.93 percent), and fertilizer expenses (–2.50 percent) also showed negative contributions in adopter farms.

Table 4. Impact of contract farming on yield of farmers

S. No.	Particulars	Percentage
	The total observed difference in yield	23.17
1)	Source of output growth	
a.	Neutral component	-1630.03
b.	Non-neutral component	1647.87
	The total estimated difference in output due to technology	17.84
2)	Input contribution	
a.	Nursery and planting / sowing (Rs/Ha)	0.02
b.	Weeding (Rs/Ha)	-0.33
c.	Plant protection (Rs/Ha)	-1.25
d.	Fertilizers (Rs/Ha)	-2.50
e.	Wages (Rs/Ha)	4.17
f.	Staking, transport & other expenses (Rs/Ha)	-1.93
	The total estimated difference in output due to input difference	5.34

In summary, the yield in adopter farms was 23.17 percent higher than in non-adopter farms, with input use accounting for 5.34 percent of this difference. The adoption of contract farming significantly enhanced yields, thereby boosting overall production in the study area.

These results are consistent with the findings of Hile et al. (2016), who reported a 19.07 percent increase in paddy productivity due to technical advancements. In their study, 11.24 percent of the productivity gap was due to different cultural practices, while 7.83 percent was attributed to input usage differences between adopter and non-adopter farmers. The findings are also in line with those of Tsinigo et al. (2016), Balakrishna (2013), and Thennarasu & Banumathy (2011).

The outcome difference resulted by adoption of technology between FPO and non contract productions was decomposed into its constituent sources and results are presented in Table 5.

The impact of FPO (Farmer Producer Organization) farming on the yield of chilli crops was estimated using decomposition analysis, and the results are presented in Table 5. The analysis revealed that the per-hectare yield of farmers who adopted FPO farming was 36.57 percent higher than that of non-adopter farmers. Technical modifications were categorized into neutral and non-neutral changes. The neutral component of the scale parameter contributed –2883.18 percent, while the non-neutral component of the slope parameter contributed 2915.68 percent.

It was estimated that out of the 36.57 percent increase in yield among adopters, 32.50 percent was attributable to the adoption of FPO farming. This indicates that yield could potentially be increased by 32.50 percent without any additional input usage.

The overall difference in yield due to variations in input use between the two groups was estimated at 4.07 percent. Among the contributing factors, fertilizer and labour wage expenditures accounted for 1.76 percent and 0.05 percent, respectively, of the yield advantage for FPO adopters over non-adopters. This suggests that FPO adopters achieved higher yields by investing more in fertilizers and labour.

Conversely, certain inputs had a negative impact on yield among adopters. Expenditure on weeding contributed –0.18 percent, indicating that higher weeding costs in non-adopter farms resulted in a 0.18 percent yield advantage for those farmers. Similar negative contributions were observed for plant protection expenses (–0.25 percent), staking, transport, and other expenses (–0.48 percent), and nursery and planting/sowing (–1.63 percent).

In summary, the yield among FPO adopters was 36.57 percent higher than that of non-adopters, with 4.07 percent of this difference explained by input usage. The adoption of FPO farming significantly improved yields, thereby boosting overall production in the study area.

These findings are consistent with those of Ketema and Kassa (2016), who reported that technological advancements in smallholder wheat production led to a 55.6 percent productivity difference between plots planted with new and old varieties. Of this difference, 30.65 percent was due to variations in input usage, while 24.07 percent was attributed to technological differences. The results also align with the findings of Kavitha and Gowri (2020), as well as Hambirao (2016).

Table 5. Impact of FPO farming on yield of farmers

S. No.	Particulars	Percentage
	The total observed difference in yield	36.57
1)	Source of output growth	
a.	Neutral component	-2883.18
b.	Non-neutral component	2915.68
	The total estimated difference in output due to technology	32.50
2)	Input contribution	
a.	Nursery and planting / sowing (Rs/Ha)	-1.63
b.	Weeding (Rs/Ha)	-0.18
c.	Plant protection (Rs/Ha)	-0.25
d.	Fertilizers (Rs/Ha)	1.76
e.	Wages (Rs/Ha)	0.05
f.	Staking, transport & other expenses (Rs/Ha)	-0.48
	The total estimated difference in output due to input difference	4.07

The results of Tables 4 and 5 were summarized in a single Fig., i.e., Fig. 1, and are explained below.

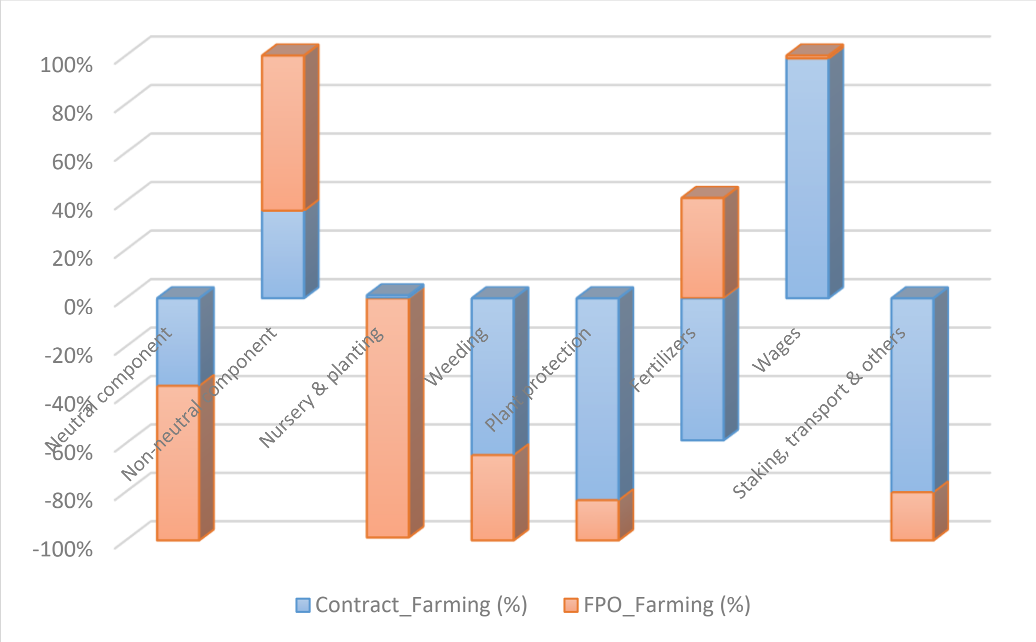

Fig. 1. Comparison of yield contribution factors under contract and FPO farming systems

The graph compares the percentage contribution of neutral effects, non-neutral effects, and input-specific factors to the yield differences between adopters and non-adopters. In both systems, yield advantages were primarily driven by non-neutral changes (improvements in input use efficiency and technical practices), while neutral components showed negative contributions. Among input factors, labour wages contributed positively under contract farming (4.17%), whereas fertilizer use (1.76%) and labour wages (0.05%) contributed positively under FPO farming. Negative contributions were observed for weeding, plant protection, staking, and nursery operations in both systems. The overall yield advantage was 23.17% for contract farmers and 36.57% for FPO farmers, highlighting that FPOs generate greater productivity gains through better technology adoption and efficient input use.

4. CONCLUSIONS

This study provides empirical evidence on the economic and productivity impacts of alternative chilli farming models—contract farming, FPO farming, and non-contract traditional farming—in Andhra Pradesh. Using partial budgeting and decomposition analysis, the study demonstrates that organized farming systems, particularly Farmer Producer Organizations (FPOs), significantly enhance both net farm income and yield performance compared to non-contract farming.

The partial budgeting analysis revealed a clear economic advantage for farmers engaged in FPO and contract farming, with FPO farmers achieving the highest net gains per hectare. Similarly, the decomposition analysis highlighted that most of the yield difference between adopters and non-adopters was due to technological improvements, rather than increased input use. This suggests that institutional models like FPOs and contract farming enable more efficient and productive farming practices through better access to quality inputs, knowledge, and market linkages.

Among the three models studied, FPO farming emerged as the most beneficial, offering the highest yield, gross income, and benefit-cost ratio. Contract farming also showed considerable promise, though to a slightly lesser extent. Non-contract farming, by contrast, lagged behind in both economic and technical performance.

These findings underscore the importance of scaling up FPOs and structured contract farming mechanisms as part of rural development and agricultural policy. Supporting such models through training, infrastructure, and policy incentives can enhance farm-level efficiency, increase rural incomes, and contribute to sustainable agricultural growth.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. Chat Gpt 10% for editing purpose.

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COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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