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Merging Interest for Sustainability Agenda: Is There a Link between Sustainable Agriculture Practices and Farm Efficiency?

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Abstract

There is a global movement towards a sustainable agricultural system, given serious concerns for the food security of future generations. However, despite this push, adopting sustainable agriculture practices has been poor, given that their positive effect is not directly evident to the farmers. In countries like Fiji, where the majority of the land is leased, not undertaking sustainable agriculture practices can lead to a crisis of food insecurity and degraded low-quality land returning to the land owners and future generations. This study utilizes the latest Agriculture Census data from Fiji to construct a non-parametric production frontier from which to estimate the levels of efficiency of each farmer. These efficiency scores are then decomposed to farmers engaged in Sustainable Agriculture Practices vis-à-vis those not undertaking any Sustainable Agriculture Practice (SAP). The results from efficiency analysis provide efficiency and productivity scores for each farmer. Further decomposing it by SAPs reveals the marked difference in efficiency and productivity scores between farmers who undertake SAPs and those who do not. The results demonstrate that those farmers who undertake SAP have efficiency and productivity levels substantially higher than those who do not. To push the sustainable agriculture agenda amongst the farmers and landowners, policymakers must demonstrate to the farmers that undertaking SAPs will not only maintain the quality of the foundation input soil but will have a significant positive effect on their farm efficiency, productivity, and thus profitability. By doing so, the interests of all stakeholders are merged, making adopting sustainable agriculture practices easier on all farms.

Keywords: sustainable agriculture, efficiency, productivity, rural households, farms

1. Introduction

The agriculture sector of small developing countries has been the primary source of the growth and development of these countries and their non-agriculture sectors. The surplus created in the agriculture sector was transferred to the non-agriculture sector, excess labor moved to the non-agriculture sector, and well-trained and mature entrepreneurs moved to the urban sector to start expanding the commercial, industrial, and service sectors. However, as these countries' non-agriculture sectors began to grow at a rate higher than the growth rate of the agriculture sector, a misconception arose amongst the urban elite that the agriculture sector was declining and no longer critical. This was further supported by the rapid growth of the urban population, a significant proportion of this growth caused by rural-to-urban migration. Pushed by the urban elite, governments of these small developing countries saw the non-agricultural sector, particularly the tourism sector, as the panacea for the rapid growth and development of the country.

However, several external shocks in the past, such as the global economic crises and their impact on domestic economies through falling tourism receipts and remittances and war, political unrest and their impact on domestic economies, disruptions in the supply chain, and rising oil prices did send silent messages to domestic policymakers that not having complete control of the critical drivers of the country can be catastrophic on its people. Despite these signals, the policymakers pushed by oligarchs continued to allocate increasing amounts of resources to grow urban-based commercial sectors. The last Covid 19 pandemic, which caused incalculable damage to the country, economy, and society, got the policymakers on the drawing board. They realized that small countries' strength lies in their natural resources and primary (agricultural) sectors.

There was a national movement to jump-start the agriculture sector, particularly commercializing it to address food security, exploit the export market, and bring in increasing dollars of foreign currency. Governments started allocating increasing resources to help new farmers enter the agriculture sector and utilize idle land. The government also began to call for commercial agriculture systems so that its primary and processed products could be developed and exported. Over the last two years, the tiny island Pacific countries have seen a surge in commercial farming and ventures targeting export markets. This has raised serious concerns about the sustainability of the critical resources supporting this sector, such as land, water, and natural resources. Environmentalists, Nongovernmental organizations (NGOs), and community leaders have also raised this issue in various forums that a rush to commercialize agriculture could jeopardize the quality of life of future generations. These concerns are peculiar to not only the Pacific but globally as well, which has led the United Nations to coordinate and fund regional and national food systems summits (Sousa, Braganca, da Silva & Oliveira, 2024). Speaking on behalf of the Pacific Island Countries, Fiji's Prime Minister, Hon. Bainimarama, while addressing the UN's Food Systems Summit in New York, noted that climate change, loss of biodiversity, land degradation, and declining productivity of fisheries are some of the significant threats to sustainable agriculture systems and food security in the Pacific region (Pacific Islands Forum Secretariat, 2021).

Therefore, efforts should be made to engage in sustainable agriculture practices. However, this call has not seen many changes in the farming system as commercial farmers see it as a stumbling block to their bottom line, maximizing profits. This issue is much more severe in most Pacific Island countries, where most agricultural land is leased. Commercial farmers are not concerned about the long term as their objective function only covers the lease period and not beyond that as the land will revert to the land owners. Unfortunately, the proponents of sustainable agriculture practices are not merging the interests of all parties. This is necessary for sustainable agriculture practices where cultivation is undertaken on leased land to be practiced. The interest can be merged if sustainability is linked to entrepreneurs' bottom line, productivity, efficiency, and profitability. In this paper, the proponents of sustainability must argue that sustainability is not only about leaving foundation resources of good quality for future generations, but it will also increase farm productivity, efficiency, and profitability. In this paper, we examine the difference in productivity and efficiency of farmers who do not undertake sustainable agriculture practices and compare it to those of farmers who practice different levels of sustainable agriculture practices. The second section of the paper briefly overviews the various problems farmers face in undertaking agriculture, which will degrade the land quality over time. The paper's third section will provide details on the theoretical basis of efficiency studies. The fourth section provides information on the methodology, the fourth section provides results and discussion, and the last section provides a summary and policy implications.

2. Sustainability and Sustainability Challenges

The agriculture sector worldwide is facing several challenges that could severely inhibit its ability to increase its production and productivity in the future to feed the rising global population. While intensive agriculture systems has been praised as a panacea for enhancing food security, some researchers, for example, McMichael and Schneider (2011) have noted that in the longer run, it destroys the capacity of agro-ecosystems for food production. These problems and challenges include climate change; a high rate of biodiversity loss; land degradation through soil erosion, compaction, salinization, and pollution; depletion and pollution of water resources (Velten, Leventon, Jager & Newig, 2015; Beus & Dunlap, 1999; Rosset & Altieri, 1997; Thrupp, 2000; Ogaji, 2005 and Peters, 2010). Some researchers argue that there should be a trade-off between economic growth and ecological and environmental balance, though it will be challenging and costly (Sharmiladevi, 2023). In light of these problems and challenges, the Brundtland Report in 1987, while presenting the overarching concept of sustainable development, a development that meets the needs of the present generation without compromising the needs of the future generation, also talks about the importance of sustainable agriculture and its role in sustainable development. Since then, much interest has been generated amongst all players linked to the agriculture sector, including policymakers and those contributing to policymakers from outside the government circles (Latruffe et al., 2016). Researchers have also attempted to establish a steady definition of sustainable agriculture but have failed. Chopra (1993) argues that organic farming methods, maintaining soil integrity, and related ecological systems are the core of sustainability. FAO (1989) defines sustainable agriculture as the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving national resources. The 1990 U.S. Farm Bill notes Sustainable agriculture as an "integrated system of plant and animal production practices having a site-specific application that will, over the long term: (i) satisfy human food and fiber needs; (ii) enhance environmental quality; (iii) make efficient use of non-renewable resources and on-farm resources and integrate appropriate natural biological cycles and controls; (iv) sustain the economic viability of farm operations; and (v) enhance the quality of life for farmers and society as a whole." (U.S. Congress, 1990). Appleby (2005) survey the definition of Sustainable agriculture and notes that in general, these definitions argue for an agriculture system that is "ecologically sound, economically viable, and socially just". He further argues that most definitions are biased towards crop agriculture mostly and ignore livestock agriculture. He calls for adding "humane" agriculture to the definition of sustainable agriculture.

Noting all the definitions of sustainability presented above, it is clear that maintaining soil structure, quality, fertility, and integrity is the core of any sustainable agriculture system. China, a country that has coped much blame for not giving due regard to environmental protection in the face of speeding up economic growth to tackle poverty, has now made enormous strides in supporting its labor-intensive small rural farms to undertake sustainable agricultural practices while making a remarkable achievement of feeding 22% of world's population with 9% of worlds arable land (Yu & Wu, 2018).

Fiji's ecological stock and its biodiversity have also contributed to the sustainability of Fiji's agriculture sector. The rich biodiversity has contributed significantly to the prosperity of the rural farmers and their farming activities in numerous ways. It supplements the households with many non-timber products, enhancing the productivity of the household members working on the farm. Materials from the biodiversity have been used to improve soil fertility. The biodiversity has also indirectly contributed to retaining soil water and moisture and replenishing groundwater for agricultural use. A large volume of work also links agriculture to the environment. This link and the importance of strengthening it was discussed at length at the 9th International Conference on Sustainable Agriculture and Environment (ICSAE-9) on 24-25 August 2022 in Surakarta, Indonesia, over the period 24-25 August 022.

However, this rich biodiversity now faces enormous threats due to the combined effects of commercial logging activities and habitat destruction, waterways and environmental contamination, over-exploitation of natural resources, introduction of exotic species such as African tulips in Fiji, and climate change. River bank erosion has contributed to the washing away of large chunks of inland arable agricultural land. Coastal erosion and saltwater intrusion have reduced the quality of arable land along the coastal areas. Changing climate patterns have witnessed extreme flooding and droughts, thus affecting the agricultural production of small farmers who do not have access to technology to deal with extreme weather conditions. Farmers' practices on their farms have been a significant cause of concern, given their impact on soil quality, microorganisms, and the environment. At a community meeting with farmers, the former Minister for Agriculture, Waterways, and Environment voiced his concern and urged the farmers to undertake sustainable agriculture practices. He noted, "One issue that has been bothering the Ministry is the lack of sustainable agriculture practices practiced at the farm level. We need to ensure that the agriculture practices undertaken by farmers are sustainable, meaning that they are not undertaken in a manner that is detrimental to the environment, the soil, and our groundwater" (Reddy, 2022, p. 1).

Therefore, sustainable environment and ecosystem management cannot be confined to the natural resource area or the protected forests but must be thoroughly championed in the agricultural areas at the farm level. Studies in other countries, such as the African region, also suggest that policymakers should make a concerted effort to support on-the-ground mitigation strategies and support sustainable agriculture practices (Amankwah, 2023). Furthermore, given that Fiji is at the forefront of climate change impacts, Climate Smart Agriculture (CSA) practices need to be adopted to minimize the negative impact of climate change. CSA practices are now becoming more widely recognized as a sustainable solution to the effects of climate change on agriculture (Brohm & Klein, 2020 and Chandra, McNamara, & Dargusch, 2018). However, their interests must be merged to sell the notion of sustainable agriculture to the farmers, households, landowners, and input suppliers. All the parties must see a stake in it instead of just emphasizing the need to protect the interest of future generations. The stake referred to here can be aptly summarized as the financial sustainability and viability of all stakeholders' core business. Bobitan, Dumitrescu & Burca, (2023) argue that the long-term sustainability of agricultural enterprises requires financial sustainability, which can be related to productivity and efficiency gains. This argument is supported by Solís, Bravo-Ureta and Quiroga, (2009), who use an input-oriented stochastic distance frontier simultaneously with a technical efficiency effects model and demonstrate that improvements in technical efficiency are financially beneficial to farm households while at the same time contributing to environmental sustainability.

3. The DEA Method of Efficiency Measurement

This study uses the Data Envelopment Analysis (DEA) method to estimate each farmer's efficiency level. There are several advantages to using this method over measuring efficiency using a stochastic frontier production, cost, or profit function. Firstly, this method does not require data on input and output prices. This is a significant advantage for cross-sectional data because the prices of inputs do not vary at a point in time; hence, parametric stochastic frontier functions cannot be estimated. Secondly, this method does not require the specification of a functional form of the production, cost, and profit functions. In the parametric stochastic approach, we must assume and specify the relevant technology's functional form. Lastly, the distance function utilized in this non-parametric does not require behavioral assumptions such as profit maximization, cost minimization, or revenue maximization.

The DEA approach has been widely used in applied economic analysis for both agriculture and non-agricultural sectors. Some of the recent studies of efficiency and productivity growth in the agriculture sector include studies by Ali, Neda & Mahdi, (2018), Gunes and Guldal (2019), Chaubey, Sharanappa, Mohanta, Mishra, and Mishra. (2022), and Galluzzo, (2018). Some of the recent studies of efficiency analysis for the non-agriculture sector include studies on the banking industry by Antunes, Hadi-Vencheh, Jamshidi, Tan, & Wanke, (2022); studies on income diversification and bank efficiency by Alhassan (2015); measurement of the environmental performance of green funds by Allevi, Basso, Bonenti, Oggioni & Riccardi, (2019); examination of capital, risk, and efficiency by Altunbas, Carbo, Gardener, & Molyneux, (2007); assessment of Chinese high-tech industries by An, Meng, Xiong, Wang & Chen, (2020); measurement of efficiency in the education sector by Aparicio, Ferrera & Ortiz, (2019); measurement of efficiency in the banking sector by Defung, Salim, & Bloch. (2016); and, measurement of efficiency and profitability of the banking sector by Eling and Jia (2019).

Estimating the efficiency of individual decision-making units index is based on the Farrell measure of technical efficiency (Farrell, 1957) and Shephard's (1970) distance function. The output distance function for a given output vector y and input vector x for a period t technology is defined as:

$$dt(y,x) = St\} \tag{1}$$

Where St represents technology in period t, the distance function can be defined as the minor factor by which output can be deflated so as to be feasible with input vector x. This concept of distance function can be illustrated using Figure 1.

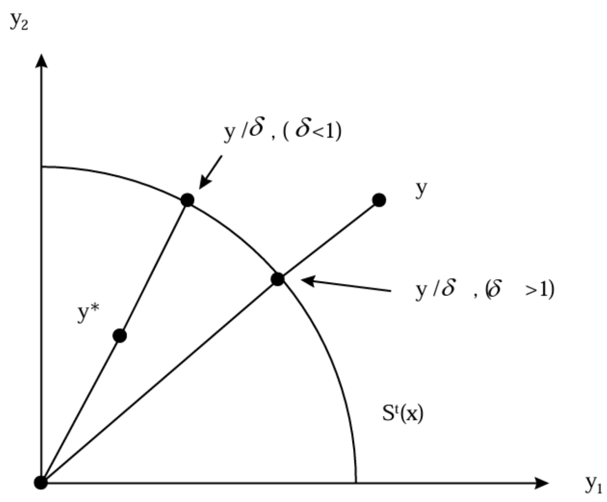

Figure 1. Illustration of Distance Function

Observations can lie above (y) or below (y*) with given technology S^t. δ is greater than one for “y” and less than one for “y*”, given the same input vector x. Since y_t is assumed to be optimal for x_t in S^t (technology in period t), $d^t(y_t,x_t)=1$. Equivalently, if y_s is optimal for x_s, then $d^s(y_s,x_s)=1$.

DEA is a non-parametric mathematical programming approach to frontier estimation. Detailed discussion of the DEA methodology is provided in Seiford and Thrall (1990), Lovell (1993), Ali and Seiford (1993), Lovell (1994), Charnes *et al*. (1995), and Seiford (1996). DEA was first advanced by Charnes, Cooper and Rhodes (1978), and led to a large number of papers extending its application.

The output-oriented measure of Farrell technical efficiency between years (s) and (t); that is, the efficiency change is equivalent to the ratio of the Farrell technical efficiency in period (t) to the Farrell technical efficiency in period (s).

$$\text{Efficiency change} = \frac{d^t(y_t, x_t)}{d^s(y_s, x_s} \tag{2}$$

In Figure 2, the firm produces at points D and E in periods s and t, respectively. In both periods, the firm is operating below the technology for that period. Therefore, the efficiency change can be described in the following equation (3) as:

$$\text{Efficiency change} = \frac{y_t / y_c}{y_s / y_a} \tag{3}$$

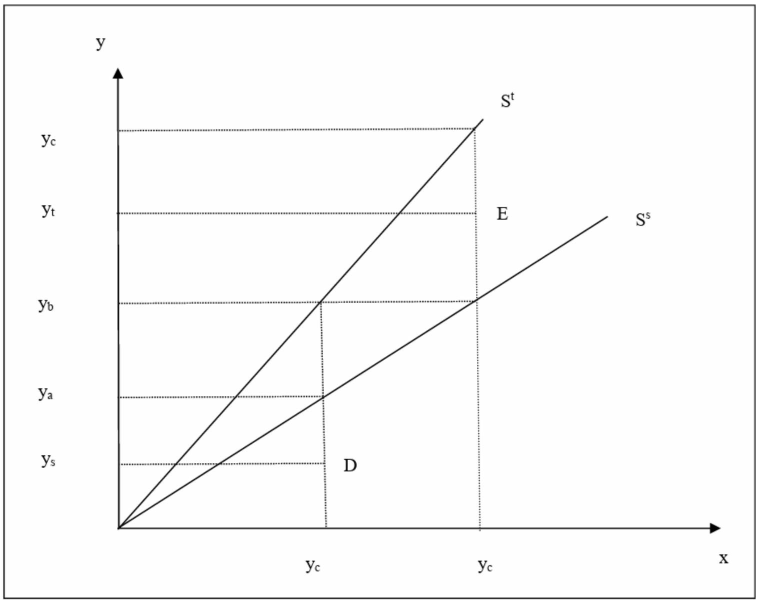

Figure 2. Illustration of Efficiency Change Measurement

4. Data and Empirical Model Estimation

4.1 Data Source

This study will utilize the latest Fiji Agriculture Census (FAC) 2020 data. The FAC 2020 was designed, pilot-tested, and administered under the purview of the author of this paper. In 2019, the survey instrument, the survey questionnaire, was designed, pilot tested, and enumerators selected and trained. The questionnaire had thirteen sections: Section 1: Household Composition; Section 2: Housing Particulars; Section 3: Land; Section 4. Crops on Farm Land; Section 5: Livestock; Section 6: Forestry; Section 7: Fishing; Section 8: Aquaculture; Section 9: Climate Change and Challenges; Section 10: Equipment; Section 11: Agriculture Services; Section 12: Food Security; and, Section 13: Labor.

Fiji Agriculture Census was undertaken from 10 to February 29, 2020, covering 70,991 agricultural households in the rural sector and selected peri-urban boundary areas where agricultural activities are commonly practiced. This comprises 99.1% of the households interviewed in rural and peri-urban areas where agriculture is commonly practiced. This was the first time that all four sub-sectors of agriculture: crop, livestock, fisheries, and forestry were covered on a complete enumeration basis. For this survey, a *household* is defined as a small group of persons who share the same living accommodation, contribute their income and wealth to acquire certain goods and services, and share the same eating arrangement. An "agricultural household" is defined as a household where the main economic activity identified is farming, i.e. it practices any agricultural activity (such as crop, livestock, fisheries, and forestry) during the reference period of the 2020 Fiji Agriculture Census (2020FAC). For this study, 4544 farmers' data were used as not all farmers provided data on the Labor and Capital variables. Hence only these farmer's data were utilized.

4.2 Empirical Model

The Efficiency change is computed by estimating the component distance functions of equation (2). Based on a constant return to scale technology, the production frontier was estimated for all crop output measured in tons of crop harvested and four inputs: Sustainable Agriculture practices, Land, Labor, and Capital. The inputs are defined as follows:

X1 = Sustainable Agriculture (SA) practice measured the number of practices carried on the farm over the last 12 months from 0= No SA practices to 5= 5 SA practices from the list below.

(i) Agroforestry on farm

(ii) Planting climate-resilient crop

(iii) Use of Ministry-recommended agriculture inputs only

(iv) Undertaking crop rotation

(v) Planting of Mucuna cover (nitrogen fixing) before the next crop.

(vi) Undertaking contour Farming

(vii) Use of organic manure

X2 = Land area under cultivation (in ha);

X3 = Labour is measured in terms of the number of full-time labor engaged on the farm;

X4 = Capital is measured in terms of the dollar value of farm equipment and machinery.

The descriptive statistics of the variables are provided in Table 1 below.

Table 1. Descriptive Statistics of Variables

Variable	Mean	Stdev	Minimum	Maximum
Crop Output	81.04	682.79	0.1D-04	23543.0
Land Area	14.25	205.82	0.1D-05	8890.9
Sustainable Agr Practices	1.77	1.26	0.0	5.0
Capital	5107.84	12149.52	100	75000
Labor	1.21	0.63	1.0	12.0

5. Results and Discussion

The results from DEA measuring each farm's output-oriented technical efficiency (converted to percentages) are presented in Table 2 below, alongside results for partial productivity. The results demonstrate that farms with no sustainable agriculture practice have much lower productivity and efficiency, 5.5 tons per ha and 45.9%, respectively. Those farms engaging in Sustainable agriculture practices have much higher productivity and efficiency, 14.1 tons per ha and 67.7% efficiency, respectively.

Table 2. Partial Productivity and Efficiency by Level of Sustainable Practice

Sustainability Category	Partial Productivity (tons/ha)	Technical Efficiency (%)
Full Sample Average	12.549 (4.941)	63.8 (0.265)
Category 0 (No SAP)	5.492 (2.049)	45.9 (0.184)
Category 1-5 (SAP undertaken)	14.080 (3.956)	67.7 (0.264)
Category 1 (One SAP)	12.156 (2.892)	74.2 (0.277)
Category 2 (Two SAP)	12.762 (2.400)	79.0 (0.286)
Category 3 (Three SAP)	16.229 (3.397)	51.3 (0.126)
Category 4 (Four SAP)	17.663 (5.735)	63.9 (0.223)
Category 5 (Five SAP)	18.964 (5.647)	69.9 (0.225)

Note: Figures in parenthesis are standard deviations.

While the average productivity for farms undertaking sustainable agriculture practices is 14.1 tons per ha, the productivity increases as the farms adopt an increasing number of sustainable agriculture practices. For example, for farms employing only one sustainable agriculture practice, their partial productivity is 12.2 tons per ha, much higher than those not undertaking any sustainable agriculture practice, 5.5 tons per ha. However, for farmers undertaking five sustainable agriculture practices, their productivity is 18.9 tons per ha. A similar trend is observed for the technical efficiency of farms. Those farms undertaking only one sustainable agriculture practice have an efficiency score of 74.2%. While this is much higher than the farms where no sustainable agriculture practices are undertaken, 45.9%. However, as farmers undertake more sustainable agriculture practices, their efficiency of production increases. As observed, those farmers who undertake five sustainable agriculture practices have a farm efficiency score of 69.9%. This result is very revealing and has significant policy implications for promoting sustainable agriculture at the farm level. Every rational farmer would aim to maximize profit. One of the ways this can be achieved without changing the technology is by raising efficiency. This study demonstrates that farmers can raise profitability by raising farm efficiency. One of the ways farm efficiency can be raised is by undertaking sustainable agriculture practices. If this becomes the farming system, all stakeholders will benefit the current and future generations.

6. Summary and Policy Implications

This study utilizes farm-level data to examine if sustainable agriculture practices contribute to improvements in the efficiency of the farms. There is a global movement towards a sustainable agricultural system, given severe concerns for the food security of future generations. However, farmers and landowners in developing countries, dependent firmly on the agriculture sector for growth and development at the micro and macro level, have kept the sustainable agenda on the back burner as their interest is maximum production and maximum profit. They do not see any link between sustainable agriculture and maximum production and profit. In countries like Fiji, where the majority of the land is leased, not undertaking sustainable agriculture practices can lead to a crisis of food insecurity and degraded low-quality land returning to the land owners and future generations. Therefore, we need to merge the interests of all these stakeholders.

The findings from this study demonstrate that farmers can substantially increase their farm productivity and efficiency by undertaking sustainable farming practices. With the efficiency and productivity gain, these farmers will have significantly higher profits vis-à-vis those farms not undertaking any sustainable agriculture practice. Therefore, by demonstrating this finding to the different stakeholders within the agriculture sector, we can merge the interests of all stakeholders towards sustainable agriculture. Lastly, this study also calls for a significant change in the discourse on sustainability, from a shift from issues with supply change bottlenecks, the commodity to product development, over-emphasis on the needs of future generations to focus more on the farm, on the current generation of farmers, the farming activities, support packages and training on sustainable practices and providing ownership to them on these sustainable technologies.

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Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Canadian Center of Science and Education.

The journal’s policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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