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ORIGINAL ARTICLE

Analyzing Key Determinants of Climate Adaptation Strategies Among Farmers: A Case Study of Farmers in Rusizi District, Rwanda

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Abstract

This study investigates the factors influencing farmers' adoption of multiple-crop cultivation as a climate change adaptation strategy in Rusizi District, Rwanda. Survey data were collected from 215 farmers, with 51.2% being female and 48.8% male. Most farmers (72.6%) had completed primary education, and the majority had 11–20 years of farming experience. Farmers widely recognized the impacts of climate change, with 82.8% reporting decreased rainfall and 87% experiencing prolonged dry seasons. Adaptation strategies such as agroforestry (81.4%), land expansion (80.5%), and crop rotation (68.8%) were prevalent, whereas early planting (14.4%) and soil and water conservation (8.4%) were less commonly adopted. Logistic regression analysis revealed that exposure to severe drought (Exp(B) = 18.0) was strongly associated with the adoption of multiple-crop cultivation, whereas agricultural income (Exp(B) = 1.0) had minimal effects. These findings highlight the importance of education, direct experiences with climate stress, and targeted interventions to promote sustainable adaptation practices in smallholder farming communities.

Key words : Climate adaptation measures, Climate change, Sustainable agriculture

1. 서 론

1. Introduction

The global climate crisis is increasingly recognized as a defining challenge of the 21st century, disrupting ecosystems, agricultural systems, and economic stability worldwide. According to World Bank(2021) assessments, climate change poses significant risks to global stability, encompassing economic security, environmental sustainability, and societal well-being. Agriculture, as one of the most climate-sensitive sectors, is particularly vulnerable due to its reliance on stable climatic conditions. Unpredictable rainfall, rising temperatures, and frequent extreme weather events threaten crop yields and food security, with smallholder farmers in developing regions being disproportionately affected (FAO, 2020).

Rwanda's agricultural sector serves as the backbone of its economy, engaging approximately 72% of the population and contributing nearly 30% to the nation's GDP (Knoema, 2021). This sector plays a crucial role in ensuring the country's food security but also for sustaining livelihoods, particularly in rural areas where the majority depend on farming as their primary

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source of income. Alongside supplying domestic markets with staples such as maize, beans, and bananas, agriculture drives export revenue through key crops like coffee and tea (FAO, 2018). The sector's heavy dependence on climatic stability makes it highly vulnerable to the increasing impacts of climate change. In addition, Rusizi District is situated in the Western Province of Rwanda, faces frequent challenges such as soil erosion, landslides, and erratic rainfall patterns that disrupt agricultural activities (Muneza, 2021). These disruptions, compounded by intensifying dry spells and heavy rainfall events, have significantly strained agricultural productivity in the region (FAO, 2022).

Climate change poses significant challenges to agricultural systems worldwide, with developing regions such as sub-Saharan Africa being particularly vulnerable due to their dependence on rain-fed agriculture (Niang et al., 2014; IPCC, 2021). Existing studies have extensively documented the impacts of climate variability on these regions, emphasizing the need for adaptation strategies to ensure food security and sustainability. Atube et al.(2023) used binary logistic regression to explore the socio-economic determinants of adaptation strategies like crop diversification and soil conservation in northern Uganda, revealing the significant roles of education, income, and farming experience. Similarly, Malinga et al.(2023) applied multinomial logit models in Ethiopia's Central Rift Valley to examine both crop-based and livestock-based adaptation strategies, finding that education and farming experience were key predictors of adoption. In Pakistan, Raza et al.(2022) demonstrated that land size and education were highly relevant to farmers' decisions to adopt climate-smart practices, highlighting the cross-regional importance of socio-economic variables in shaping adaptation behaviors.

Smallholder farmers, who form the majority of Rwanda's agricultural workforce, are disproportionately affected by these climate- induced challenges. Limited access to financial resources, technology, and institutional support leaves them ill-equipped to adapt to changing climatic conditions. According to the European Union(2022), promoting sustainable practices such as soil conservation, water management, and multiple-crop cultivation is essential to mitigating the adverse effects of climate change. These practices not only enhance resilience but also ensure the long-term viability of agriculture in vulnerable areas.

Recent research has extensively examined how farmers' behaviors are adapting in response to climate change. A systematic review by Mase et al.(2017) analyzed 119 studies to understand farmers' perceptions of climate change and their subsequent adaptation actions. The review found that while a majority of farmers acknowledge changes in weather patterns, there is variability in their beliefs about the causes of climate change, which influences their willingness to adopt adaptive practices. Similarly, a study by Niles et al.(2016) surveyed over 5,000 farmers across four countries, revealing that personal experience with climate-related events significantly increases the likelihood of adopting adaptive measures such as altering planting dates or crop varieties. However, while existing studies suggest that farmers' behaviors are shifting in response to climate change, few have explored how socio-economic factors and drought exposure are associated with the adoption of multiple-crop cultivation.

Therefore, this study aimed to examine the factors influencing the adoption of multiple-crop cultivation as a climate change adaptation strategy among smallholder farmers in Rusizi District, located in the western region of Rwanda. By investigating socio-economic variables such as education, farming experience, income, and exposure to severe drought, this study might provide insights into designing targeted interventions to enhance resilience and sustainability in climate-vulnerable farming communities in developing countries.

2. Study Area and Methods

2.1. Study area

This study was conducted in Rusizi District, one of the 30 districts of Rwanda, covering an area of 959 km² (Fig. 1). The district has a population of 485,529, with 66.6% residing in rural areas and relying primarily on agriculture for their livelihoods (NISR Census Report, 2022). Located in southwestern Rwanda along the border with the Democratic Republic of the Congo, Rusizi District features distinct climatic characteristics shaped by its topography and proximity to Lake Kivu. The district experiences a tropical highland climate, with daytime temperatures averaging around 28°C during the dry seasons (June to September and January to February), while nighttime temperatures can drop to approximately 16°C (Climates to Travel, 2023). The region undergoes two primary wet seasons, from March to May and October to December, bringing heavy rainfall typical of Rwanda's bimodal rainfall distribution. While precipitation is essential for rain-fed agriculture, its variability and intensity pose challenges during wet periods (Rwanda Environment Management Authority, 2021).

Rwanda's diverse topography, characterized by mountainous terrain and varying altitudes, exacerbates the effects of climate change. Rusizi District is particularly vulnerable due to its reliance on rain-fed agriculture, which is directly affected by climatic variability. Erratic rainfall patterns result in shorter growing seasons, delayed planting times, and reduced crop yields. The district's hilly terrain exacerbates the risk of soil erosion and landslides during heavy rains, further challenging agricultural productivity (UNDP, 2021). Most farmers in Rusizi engage in traditional subsistence farming, cultivating staple crops such as maize, beans, bananas, and cassava. Additionally, high-value crops like coffee and tea are cultivated for export, contributing significantly to the local economy (World Bank, 2020). Livestock farming, including cattle, goats, and poultry, complements crop production by providing protein sources and manure for fertilization, reflecting the district's reliance on integrated farming systems (Rwanda Environment Management Authority, 2021).

Despite its agricultural potential, Rusizi District faces numerous challenges, including erratic rainfall, prolonged dry spells, soil erosion, and limited access to modern technologies, credit facilities, and markets. These barriers hinder agricultural productivity and reduce climate resilience (World Bank, 2020; UNDP, 2021). Strategies such as crop diversification, intercropping, and agroforestry are commonly employed to optimize land use and mitigate risks (FAO, 2022). However, these efforts are often undermined by insufficient access to quality seeds, fertilizers, and irrigation systems, as well as poor rural infrastructure, including inadequate roads and storage facilities. These limitations exacerbate post-harvest losses and reduce farmers' market connectivity. Addressing these challenges through climate-smart agriculture, improved irrigation, and enhanced access to agricultural inputs is critical for ensuring sustainable agricultural development in the region (Rwanda Environment Management Authority, 2021).

2.2. Methods

Survey data were collected from 215 farmers in Rusizi District using a random sampling technique. A face-to-face interview was conducted in June 2023 following a pilot survey. The

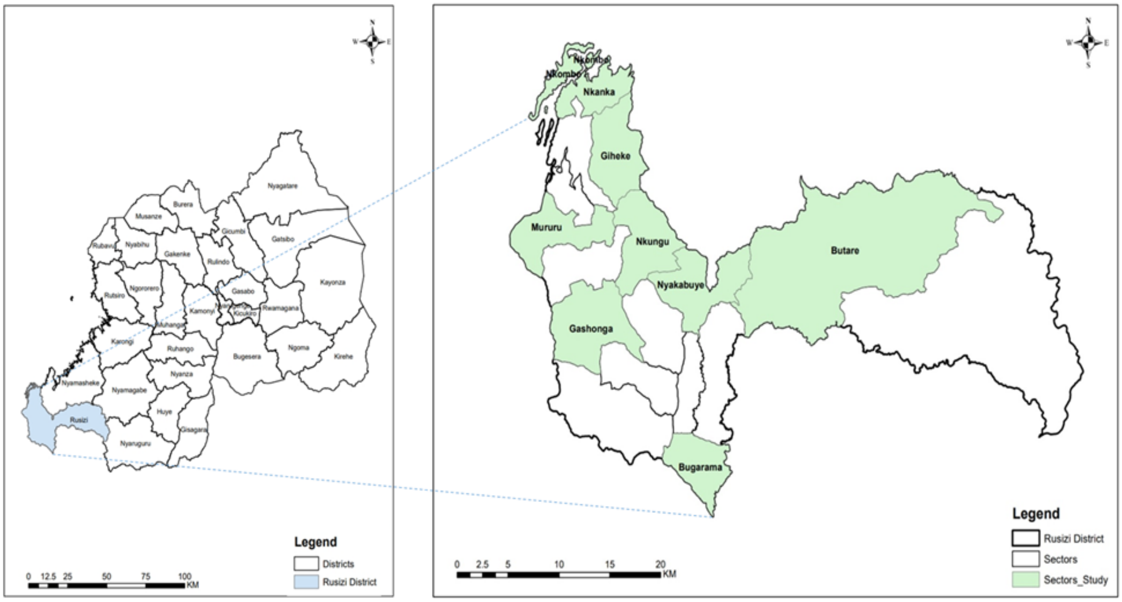

Fig. 1. Study area in Rusizi District, Rwanda.

survey was designed to gather information on farmers' socio-economic characteristics, perceptions of climate change, and adaptation strategies to address its impacts.

In this study, descriptive statistics and frequency analysis were utilized to examine the socio-economic characteristics, perceptions of climate change, and adaptation practices of farmers in Rusizi District. Logistic regression analysis was conducted to identify the socio-economic and environmental factors influencing farmers' adoption of specific climate adaptation practices.

Logistic regression was conducted using SPSS Statistics Version 20.0 to model the probability of a farmer adopting a specific adaptation measure (dependent variable) based on various socio-economic predictors (independent variables). This method is particularly suitable as it models the relationship between one or more independent variables and a binary dependent variable—whether or not a farmer adopts certain adaptation practices (Menard, 2002; Hosmer et al., 2013).

The logistic regression model was optimized by using maximum likelihood estimation (MLE) to find the best-fitting parameters. The model is expressed as: $\log(p/1-p) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta n X n$ where p is the probability of a farmer adopting a given adaptation measure. β_0 is the intercept. $\beta_1, \beta_2, \cdots, \beta_5$ are the coefficients for the independent variables. $X_1, X_2, \cdots, X_5$, which include factors such as age, education level, farming experience, agricultural income, and experience of severe drought in the past 5 years (Peng et al., 2002; Gujarati & Porter, 2009).

In addition, the model assumes that age reflects the farmer's life stage and accumulated agricultural experience. Older farmers may possess valuable traditional knowledge but might be less inclined to adopt new practices compared to younger, more adaptable farmers. Education equips farmers with the skills and knowledge necessary to understand climate risks and imple-

Table 1. Socio-economic characteristic of farmers in Rusizi District

Category	Survey items	Frequency	Ratio (%)	χ^2
Gender	Female	110	51.2	0.6
	Male	105	48.8	
Age (Years)	19-35	43	20	8.2*
	36-45	67	31.2	
	46-55	51	23.7	
	56-65	35	16.3	
	66-75	19	8.8	
Education	No education	40	18.6	14.3***
	Primary	156	72.6	
	Secondary	18	8.4	
	University	1	0.5	
Farming experience (Years)	1-10	35	16.3	11.9**
	11-20	69	32.1	
	21-30	62	28.8	
	31-40	35	16.3	
	41-50	13	6.1	
	41-More	1	0.5	

Category	Mean	Std. Err.
Annual agricultural income (RWF[a])	227,937	206,630
Farm size (Hectare)	0.4	0.4
Livestock ownership	0.7	0.5
Access to information (Min.:1, Max.:3)	1.1	0.4

***p<0.001, **p<0.05, *p<0.1; [a] Exchang rate USD 1.00 = RWF (Rwandan Francs) 1,379.92 (2024.12)

ment adaptation strategies, with higher education levels increasing the likelihood of adopting practices like crop diversification. Farming experience represents practical knowledge gained over time, enabling farmers to recognize climate variability patterns and prioritize strategies such as diversification. Agricultural income indicates financial capacity, which significantly impacts the ability to invest in adaptive measures like climate-resilient seeds or multiple-crop cultivation. Finally, recent exposure to severe drought serves as a critical motivator for adaptation, encouraging farmers to diversify crops to reduce risks and enhance resilience by spreading potential losses across various crops.

3. Results

Table 1 presents the socio-economic characteristics of farmers in Rusizi District. The sample comprised 51.2% female farmers and 48.8% male farmers, with no significant gender difference observed (χ^2 = 0.6). Farmers aged 36-45 years formed the largest group, followed by those aged 46-55 years. Younger farmers aged 19-35 accounted for 20% of the sample (n = 43), while those aged 56-65 represented 16.3%. The smallest group was farmers aged 66-75, making up 8.8% of the sample. Age differences were statistically significant (χ^2 = 8.2). Regarding education, the majority of farmers (72.6%) had completed primary education. Meanwhile, 18.6% reported

Table 2. Farmers' perception of climate change in Rusizi District

Category	Strongly disagree		Disagree		Neutral		Agree		Strongly agree	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Less rainfall	0	0.0	3	1.4	28	13.0	178	82.8	6	2.8
Long period of dry season	0	0.0	0	0.0	6	2.8	187	87.0	22	10.2
Rainfall starts late and ends early	0	0.0	2	0.9	42	19.5	167	77.7	4	1.9
Increase in temperature	0	0.0	33	15.4	88	40.9	92	42.8	2	0.9
Increase in heavy and long period rainfall	2	0.9	108	50.2	19	8.8	58	27.0	28	13.0

Table 3. Farmers' experience of climate change and recycling of crop residues

Category	Yes (%)	No (%)
Experience of climate change	89 (41.4)	126 (58.6)
Recycling of crop residues	137 (63.7)	78 (36.3)

having no formal education, 8.4% had attained secondary education, and only 0.5% had a university education. The differences in educational attainment were highly significant (χ^2 = 14.3). In terms of farming experience, the majority of farmers had 11-20 years of experience (32.1%), followed by those with 21-30 years (28.8%). Equal proportions of farmers (16.3%) had 1-10 years and 31-40 years of experience. Smaller groups included those with 41-50 years of experience (6.1%), and only one farmer (0.5%) had over 50 years. The distribution of farming experience was statistically significant (χ^2 = 11.9).

Table 2 summarizes farmers' perceptions of specific climate changes, including rainfall patterns, dry seasons, and temperature increases. A majority of farmers (82.8%) agreed that rainfall had decreased, while 13% remained neutral, 2.8% strongly agreed, and only 1.4% disagreed. Regarding the length of dry seasons, 87% of respondents agreed that the dry season had become longer, with 10.2% strongly agreeing. A small proportion (2.8%) remained neutral, and no disagreement was reported. Most farmers (77.7%) perceived that rainfall started later and ended earlier, with 19.5% neutral. Strong agreement was minimal (1.9%), and only 0.9% disagreed. Temperature increase was also widely perceived, with 42.8% agreeing and 40.9% remaining neutral. However, 15.4% disagreed, and only a very small proportion strongly agreed. For overall changes in climate patterns, 27% of respondents agreed, and 13% strongly agreed. However, a majority (50.2%) disagreed, while 8.8% were neutral and only 0.9% strongly disagreed.

Table 3 presents farmers' responses regarding their experiences with climate change and their recycling of crop residues. Among the respondents, 89 farmers (41.4%) reported experiencing climate change, while 126 farmers (58.6%) stated they had not. This suggests that the majority of farmers did not perceive or recognize significant climate changes in their area. Regarding crop residue recycling, 137 farmers (63.7%) reported engaging in this practice, while 78 farmers (36.3%) indicated that they did not. These findings highlight a relatively high level of

Table 4. Actual adaptation measures taken by farmers in Rusizi District

Adaptations measures	Number	%
Different crops varieties	134	62.3
Increase in cultivated land	173	80.5
Crop rotation and diversification	148	68.8
Agroforestry (trees planting)	175	81.4
Soil and water conservation (furrow and land cover)	18	8.4
Early planting	33	14.4

Table 5. Logistic regression for multiple-crop cultivation in climate change

Category	B	S.E	Wald	Exp(B)
Age	0.024	0.056	0.187	1.025
Education level	0.660	0.421	2.453	1.935
Farming experience	-0.031	0.058	0.276	0.970
Agricultural income	0.000***	0.000	12.407	1.000
Experience of severe drought over the last 5 years	2.893***	0.482	36.015	18.045
Constant	-4.319	1.794	5.797	0.013

***$p<0.001$; -2LL=144.4; Chi-Square(χ^2) = 153.5; Hosmer & Lemeshow χ^2 = 11.4; Cox&Snell R^2 = 0.5; Nagelkerke R^2 = 0.7

adoption of residue recycling among the surveyed farmers.

Table 4 shows the adaptation measures adopted by farmers and the proportion of farmers who recognized each as a response to climate change. Agroforestry emerged as the most widely adopted strategy, with 81.4% of farmers implementing this measure. Expanding cultivated land was also common, with 80.5% perceiving it as an effective response to climate change. Crop rotation and diversification were practiced by 68.8% of farmers, while 63.7% engaged in recycling crop residues, reflecting the widespread adoption of these approaches. Using different crop varieties was another notable strategy, implemented by 62.3% of farmers. In contrast, soil and water conservation was the least adopted measure, with only 8.4% of farmers reporting its use. Early planting was practiced by 14.4% of respondents. Additionally, 41.4% of farmers acknowledged experiencing climate change, highlighting varying levels of awareness and recognition of its impacts on agricultural practices.

Table 5 presents the results of the logistic regression analysis, demonstrating a high explanatory capacity with a Nagelkerke R^2 value of 0.7, which accounted for 70% of the variance in adoption behavior. The model fit was statistically significant (χ^2 = 153.5), and the Hosmer-Lemeshow test indicated no significant lack of fit.

The effect of age on the adoption of multiple-crop cultivation was minimal and statistically insignificant. However, previous researches found that socio-demographic factors, including age, often played a secondary role compared to direct influences such as experiencing climate stressors or having access to resources (Oyetunde-Usman and Shee, 2023). These studies emphasized that while age can indicate life stage or accumulated experience, it does not consistently predict adaptation behavior, particularly in homogeneous farming communities where other constraints dominate. Research such as that by Miller and Bryan(2021) noted that older farmers might face barriers to adopting new practices due to limited willingness to take risks or adapt to technological advancements. Younger farmers, in contrast, are more likely to explore diverse strategies and adopt climate-smart practices (Miller and Bryan, 2021; Oyetunde-Usman and Shee, 2023).

Moreover, education was found to be an insignificant variable. However, previous studies, such as Aryal and Marenya(2021), have identified education as a significant factor, highlighting its role in equipping farmers with the skills and knowledge needed to assess risks and implement effective climate-smart agricultural strategies. Diana et al.(2022) supported the finding that higher education levels enhance adaptive capacity. Educated farmers tend to have better access to information, improved decision-making skills, and a higher likelihood of adopting resilient farming practices, such as using drought-resistant seeds or implementing crop rotation (Aryal and Marenya, 2021; Nor Diana et al., 2022).

Agricultural income was a statistically significant predictor of adoption, although its practical relevance remained limited. The odds ratio (Exp(B) = 1.000) indicated a very minimal increase in the likelihood of adoption with higher income. This suggested that while income stability played a role in supporting adaptation, it may not have been the primary driver for adopting multiple-crop cultivation in this study. Nevertheless, previous research, such as that by Diana et al.(2022), emphasized that income significantly drove the adoption of climate-smart practices by providing the financial capacity to invest in inputs such as seeds and equipment. The minimal effect observed here may reflect the homogeneity of income levels among farmers in Rusizi District, where economic constraints limit variability in adaptation behaviors regardless of income differences (Nor Diana et al., 2022).

The experience of severe drought was the most significant factor influencing adoption. The odds ratio (Exp(B) = 18.045) showed that farmers who experienced severe drought were 18 times more likely to adopt multiple-crop cultivation compared to those who did not. Similarly, Miller and Bryan(2021) highlighted barriers to adopting climate change adaptation measures, including multiple cropping, among smallholder farmers. In contrast, Oyetunde-Usman and Shee (2023) observed that farmers exposed to drought were significantly more likely to adopt climate-smart practices, such as drought-tolerant crops and multiple cropping systems. Aryal and Marenya(2021) similarly emphasized that direct exposure to climate stressors, like drought, motivates farmers to diversify crops as a risk management strategy. These findings indicate the need for interventions that raise awareness about climate risks and provide targeted support to farmers directly affected by climate stressors to strengthen their adaptive capacity (Aryal and Marenya, 2021; Miller and Bryan, 2021; Oyetunde-Usman and Shee, 2023).

4. Summary and Conclusions

This study examined the factors influencing farmers' adoption of multiple-crop cultivation as an adaptive strategy to climate change in Rusizi District, Rwanda. The findings revealed that most farmers were middle-aged (36–55 years), with primary education being the predominant level of schooling. A significant proportion had 11 to 30 years of farming experience, reflecting substantial practical knowledge. Farmers demonstrated proactive efforts to address climate challenges, employing various adaptation measures such as crop diversification, agroforestry, and residue recycling. Among these strategies, agroforestry (81.4%), expanding cultivated land (80.5%), and crop rotation (68.8%)

were the most widely adopted. Recycling crop residues (63.7%) and adopting different crop varieties (62.3%) were also notable practices. However, less widely implemented strategies, such as early planting (14.4%) and soil and water conservation (8.4%), highlighted the need for further support and awareness initiatives in these areas.

Logistic regression analysis revealed that the experience of severe drought was the most significant determinant of multiple-crop cultivation adoption. This underscores the critical role of direct exposure to climate stressors in shaping adaptive behavior. Education level also emerged as a significant predictor, indicating that better-educated farmers are more likely to recognize the benefits of crop diversification and adopt innovative practices. Interestingly, agricultural income had a statistically significant but negligible impact, suggesting that financial capacity alone may not drive adoption in resource-constrained settings. These findings highlight the interplay between socio-economic factors and climate stressors in motivating adaptation.

Promoting agricultural practices that address climate challenges is essential for enhancing farmers' resilience and sustainability. Targeted education and outreach efforts should focus on equipping farmers, particularly those who have directly experienced climate impacts, with the tools and knowledge necessary for sustainable adaptation. The findings emphasize the need for interventions that build on existing awareness while increasing access to education, technical support, and financial incentives. Risk perception, institutional frameworks, and access to knowledge may play crucial roles in farmers' decision-making processes.

This study has limitations. The study utilized cross-sectional data, which restricts the capacity to observe or analyze temporal changes and trends. While the sample size was representative of Rusizi District, its findings may not be generalizable to other regions with different socio-economic and environmental conditions. Furthermore, the study used farmers' perceptions and experiences of drought as proxies for climate stressors rather than objective climate data. Although perceptions are crucial for understanding behavior, incorporating meteorological data on rainfall, temperature changes, and drought severity could provide a more robust analysis.

Future research should consider adopting a mixed-methods approach, combining quantitative surveys with qualitative interviews, to gain deeper insights into adaptation drivers. Expanding the study to include vaious regions with diverse socio-economic and ecological conditions would improve the generalizability of findings and provide comparative perspectives. Additionally, future studies could explore the influence of social norms, peer networks, and community-based organizations on farmers' decision-making processes. Investigating the role of institutional frameworks, such as government programs and credit systems, and social networks in facilitating or hindering adaptation could provide valuable insights into external support mechanisms.

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