African Journal of Climate Change and Resource Sustainability
ajccrs.eanso.org
Volume 4, Issue 1, 2025
Print ISSN: 790-962X | Online ISSN: 790-9638
Title DOI: https://doi.org/10.37284/2790-9638

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Tea Farmers' Perceptions of the Influence of Climate Variability on Dodder Occurrence in Nandi County, Kenya

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Article DOI: https://doi.org/10.37284/ajccrs.4.1.2605

Date Published:

13 January 2025

Keywords:

Dodder, Climate Variability, Famers' Perceptions, Tea Farming, Parasitic Plants, Man Kendall.

ABSTRACT

Climate variability continues to adversely impact agricultural systems globally. From the literature, it is reported that there has been an unprecedented emergence of pests and diseases associated with climate change and variability among other factors. In Kenya, crop cultivation and yield are affected primarily by changing climatic conditions, pests, and diseases. Of major concern in counties of Kenya, are the impacts of climate variability and parasitic dodder (Cuscuta spp.) on tea cultivation and production. From the literature, little is reported on the continuing invasion and effects of parasitic dodder on tea farming. This study aimed to assess tea farmer perceptions on the role of climate variability on the occurrence of dodder in Nandi. An exploratory survey design was utilized for this study. Using the Yamane Formula, a sample size of 392 was drawn from the Kenya Tea Development Agency tea farmers to represent the study. Primary data obtained from the administered questionnaires was extracted, collated, classified, and analysed ($p \leq 0.05$) with the aid of the Statistical Package of Social Sciences. Rainfall and temperature data for the County was obtained from the Kenya Meteorological Department from 1992 to 2022. Mann-Kendall Trend Analysis showed a significant increase in temperature denoted by a Sen's slope= 0.031 and a strong positive correlation of Kendall's Tau 0.554 indicated an increase at $p<0.000$. Rainfall showed an increasing trend Sen's slope= 5.618 was not statistically significant at p= 0.341 with a weak correlation of Kendall's Tau= 0.123. On the influence of rainfall and temperature on dodder occurrence, 95.6%, and 68.9% of the respondents perceived that long rainy (March to May) and cold (June to August) seasons increased its intensity. While 69.8% of the respondents perceived a moderate intensity of dodder during the hot season (December to February). In conclusion, climate variability has influenced the spread of dodder on tea farms. The study recommends further research to examine the effectiveness of different Integrated Pest Management strategies under varying climate conditions.

APA CITATION

Mong'o, F. J., Koske, J. K. & Muriuki, J. N. (2025). Tea Farmers' Perceptions of the Influence of Climate Variability on Dodder Occurrence in Nandi County, Kenya. *African Journal of Climate Change and Resource Sustainability*, *4*(1), 1-11. https://doi.org/10.37284/ajccrs.4.1.2605.

CHICAGO CITATION

Mong'o, Faith Jepchirchir, James Kibii Koske and John Njagi Muriuki. 2025. "Tea Farmers' Perceptions of the Influence of Climate Variability on Dodder Occurrence in Nandi County, Kenya", *African Journal of Climate Change and Resource Sustainability* 4 (1), 1-11. https://doi.org/10.37284/ajccrs.4.1.2605.

Article DOI : https://doi.org/10.37284/ajccrs.4.1.2605

HARVARD CITATION

Mong'o, F. J., Koske, J. K. & Muriuki, J. N. (2025) "Tea Farmers' Perceptions of the Influence of Climate Variability on Dodder Occurrence in Nandi County, Kenya", *African Journal of Climate Change and Resource Sustainability*, 4(1), pp. 1-11. Doi: 10.37284/ajccrs.4.1.2605.

IEEE CITATION

F. J. Mong'o, J. K. Koske & J. N. Muriuki "Tea Farmers' Perceptions of the Influence of Climate Variability on Dodder Occurrence in Nandi County, Kenya", AJCCRS, vol. 4, no. 1, pp. 1-11, Jan.

MLA CITATION

Mong'o, Faith Jepchirchir, James Kibii Koske & John Njagi Muriuki. "Tea Farmers' Perceptions of the Influence of Climate Variability on Dodder Occurrence in Nandi County, Kenya". *African Journal of Climate Change and Resource Sustainability,* Vol. 4, no. 1, Jan. 2025, pp. 1-11, doi:10.37284/ajccrs.4.1.2605.

INTRODUCTION

Dodder is a holoparasitic plant of the: Kingdom- Plantae; phylum- Tracheophyta; class- *Spermatopsida*; order- *Solanales*; family- *Convolvulaceae* (Morning glory) and genus- *Cuscuta* (Dawson *et al*., 1994; Sarić-Krsmanović, 2020). There are about 200 species globally (Olszewski, 2019) believed to have originated from the northern parts of America (Sarić-Krsmanović and Vrbnicanin, 2015). Dodders are characterised by yellow, green-yellow to orange twinning stems (Sandler and Ghantous, 2019). They lack chlorophyll and thus require suitable host plants to complete their life cycle (McRitchie, 1990). Dodder species have root-like structures called haustoria which penetrate the host vascular system to extract nutrients (Zhuang *et al*., 2018; Zhang *et al*., 2024).

Globally, dodder species have threatened crops of major economic importance such as alfalfa, coffee, tea, tomatoes, and sugar beets among others (Masanga *et al*., 2021; Cai *et al*., 2022; Mong'o *et al*., 2024). In the eastern part of Africa, dodder has destroyed agricultural crops. In Tanzania, *Cuscuta reflexa* (Roxb) have invaded onion farm zones incurring up to 50% loss (Nyoni and Bayo, 2021). Kagezi *et al*., (2021) reported that dodder has caused economic loss in coffee farming in Busoga, Uganda. In Sudan, field dodder has been reported to have caused a reduction in the yield of onions, tomatoes, and Jew mallows (Zaroug *et al*., 2014).

In Kenya, *Cuscuta* species have been reported to have spread to about 12 counties majorly in the Eastern, Western, and Rift Valley regions (Masanga *et al*., 2021). (Ngare *et al*., 2020) reported that dodders destroyed ornamental plants in urban cities in Kenya, particularly Mombasa city. In Homa Bay County, *Cuscuta campestris* (Yunker) have destroyed trees and shrubs leading to ecosystem fragmentation (Orwah, 2022). Findings by Chepkirui, (2020) showed that tea is the most suitable dodder host in Kericho County. Once the dodder attaches itself to a tea bush, it sucks water and nutrients essential for growth. This changes the plant physiology and eventually, reduces performance to produce viable yields (Masanga *et al*., 2021).

In Nandi County, *Cuscuta* species have negatively impacted tea production by reducing yields (Yego *et al*., 2022; Mong'o *et al*., 2024). This poses economic challenges, particularly as climate variability continues to influence agricultural practices (Bett, 2018; Karki *et al*., 2020; Mairura *et al*., 2021). Changes in temperature and rainfall patterns are known to exacerbate the spread of invasive species like dodder (Phophi *et al*., 2020). However, little or no research has been done to examine climate variability impacts on the spread of dodder in tea farming in Nandi County.

The purpose of this study is to assess tea farmers' perceptions of the influence of climate variability on the occurrence of dodder in Nandi County. By filling this knowledge gap, the research aims to provide recommendations that can inform local farmers and policymakers on mitigating the adverse effects of dodder infestation on tea. This study will provide insights into how climate change interacts with invasive species in the context of Kenyan agriculture, offering practical solutions to enhance crop resilience.

Article DOI : https://doi.org/10.37284/ajccrs.4.1.2605

Research Objectives

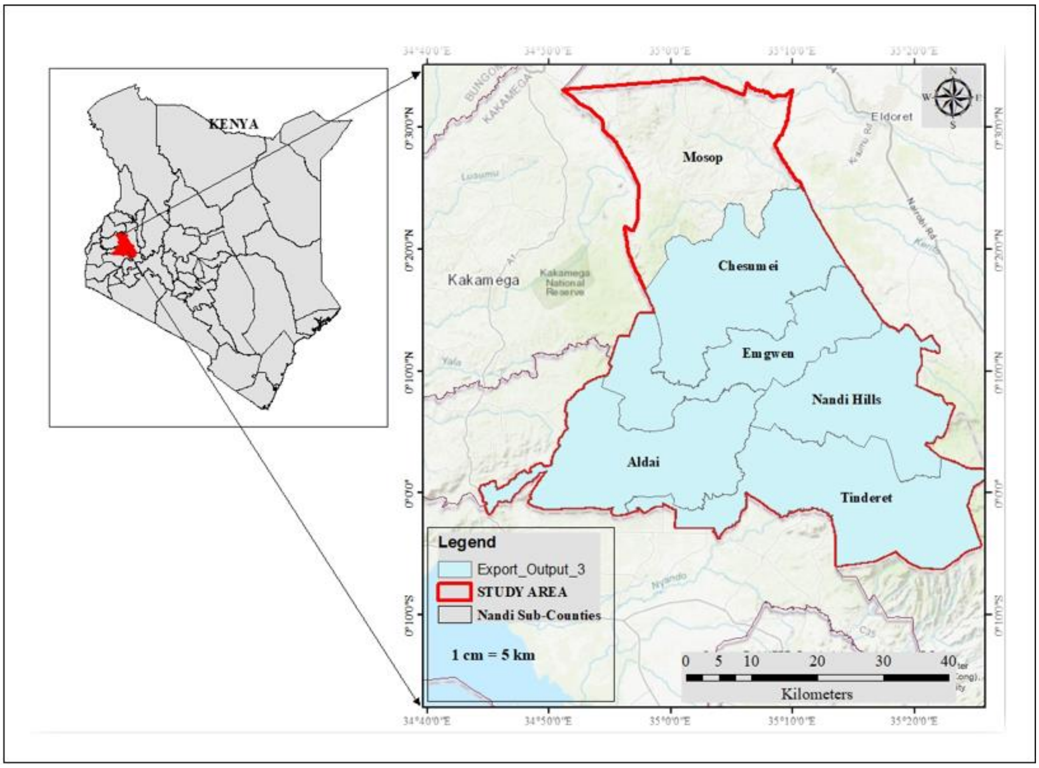
The research aimed to achieve the following objectives for the study in Nandi County:

- To examine the trends in climate variability from 1992 to 2022 in the study area.
- To assess tea farmers' perceptions of the effects of climate variability (temperature and rainfall) and the occurrence of dodder.
- To assess tea farmers' perceptions of the effects and control of dodder on tea farms.

METHODOLOGY

Nandi County, in Kenya's North Rift, covers 2,855.8 km² between longitudes 34°45′E and 35°25′E and latitudes 0°35′N and 0°06′S as shown in Figure 1. It has an altitude of 1300m above the sea level (NCIDP, 2018). The average temperature ranges from 18℃ to 22℃. With its heterogeneous terrain, the northern parts of the County receive rainfall ranging from 1300mm to 1600mm suitable for maize, while the southern half experiences 2000mm annually best for tea farming (NCIDP, 2023). Long rainy seasons are experienced from March to May, and short rainy seasons from September to November. A dry spell is experienced from December to late February while cold seasons are experienced in June and August (CADP 2019).

Figure 1: Map of the Study Area.



Study Design

This research adopted an exploratory survey design to assess the perceptions of tea farmers on the nexus of climate variability (rainfall and temperature), and dodder infestation. This design was suitable for the data as it investigates new phenomena in the context of Nandi. Primary data were collected using a semi-structured questionnaire, alongside a Likert scale. Additionally, historical data on temperature and rainfall from 1992 to 2022 were obtained from the Kenya Meteorological Department (KMD) in Nandi County to analyse long-term climate trends.

Sample Size

The sample frame for this study was drawn from tea households registered and the Kenya Tea Development Agency (KTDA). The sample size of 392 was obtained by applying the Yamane Formula (1967) to the 19,754 KTDA tea farmers:

African Journal of Climate Change and Resource Sustainability, Volume 4, Issue 1, 2025
Article DOI : https://doi.org/10.37284/ajccrs.4.1.2605

$$n = \frac{N}{(1+N(e)^2} \quad (1)$$

Where N was the total number of tea-growing households, n was the sample size, and e was the margin error taken as 0.05 at a 95% confidence level. Therefore,

$$n = \frac{19{,}574}{(1 + 19{,}574(0.05)^2}$$

$$n = 392.3034$$

The sample size was proportionally distributed to the population of tea farmers delivering their tea to the two KTDA factories: Chebut and Kaptumo.

Table 1: Sample Frame for the Study

S/N	Factory	No. of TBCs	Population	Sample size
1	Chebut	64	12,084	242
2	Kaptumo	32	7,490	150
Total		97	19,574	392

Data Analysis

Statistical variables (rainfall and temperature) were analysed using linear regression to examine the relationship between climate variables and time while Mann-Kendall Trend Analysis (Mann 1945; Kendall 1975) examined the significance of these trends. Descriptive statistics (mean and standard deviation) summarized farmers' perceptions of climate variability and dodder infestation.

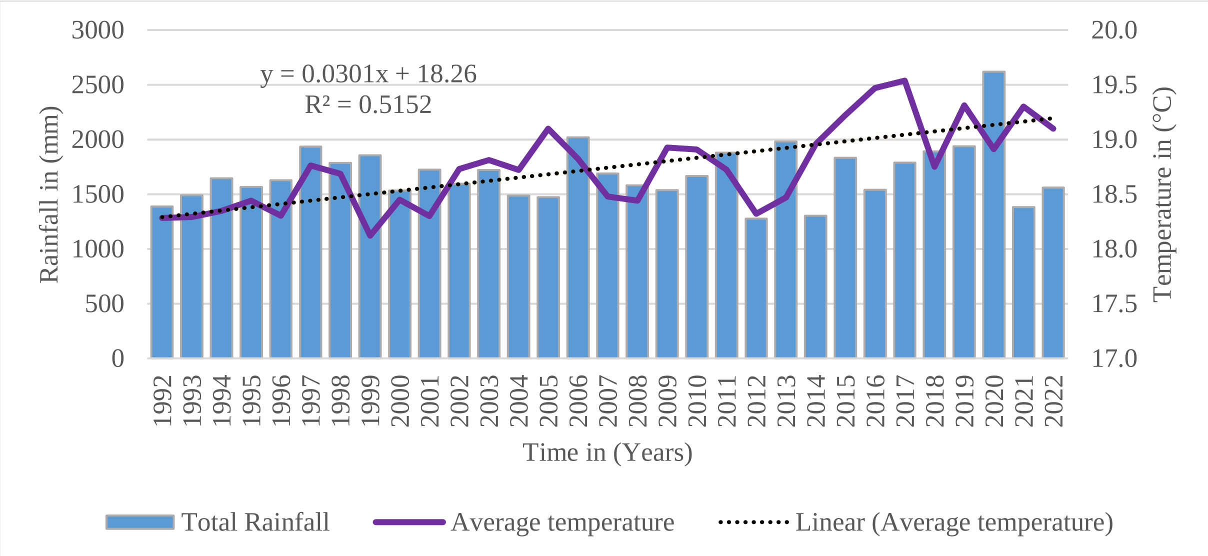
RESULTS AND DISCUSSION

Nandi County Climate Variability from 1992 to 2022

Temperature Variability

The results from the trend line show that mean annual temperatures have been rising significantly. The highest temperature was recorded in 2017 at 19.5 °C and the lowest was in 1999 at 18.1 °C. The equation y = 0.0301x + 18.26 indicated that the mean temperature had been rising by 0.0301℃ yearly. The Coefficient of Determination R^2 represented by the value (0.5152) explained that approximately 51.52% of the variability in temperature could be due to the linear relationship with the year. To test monotonic temperature trends, the Mann-Kendall test indicated a strong positive relationship for temperature, with Kendall's Tau (τ) = 0.554 at an increase of 0.031°C per year which was significant at $p < 0.0001$

Figure 2: Mean Annual Temperature from 1992 to 2022.



Article DOI : https://doi.org/10.37284/ajccrs.4.1.2605

Temperature was analysed seasonally to assess its impacts on dodder occurrence. This was important in identifying how seasonal variations in temperature could significantly influence the growth and spread of dodder, thus affecting its interaction with tea crops throughout the year.

Table 2: Mann Kendall Trend Analysis for Seasonal Rainfall from 1992- 2022

Seasons	Mean	Std. dev.	Kendall's Tau	S	*p*-value	Sen's slope	Lower bound (95%)	Upper bound (95%)
DJF	57.482	1.187	0.245	113	0.057	0.05	0.000	0.100
MAM	57.008	1.639	0.420	195	0.001	0.086	0.043	0.144
JJA	54.176	2.019	0.574	266	<0.0001	0.150	0.094	0.200
SON	56.218	1.164	0.455	211	0.000	0.081	0.042	0.120

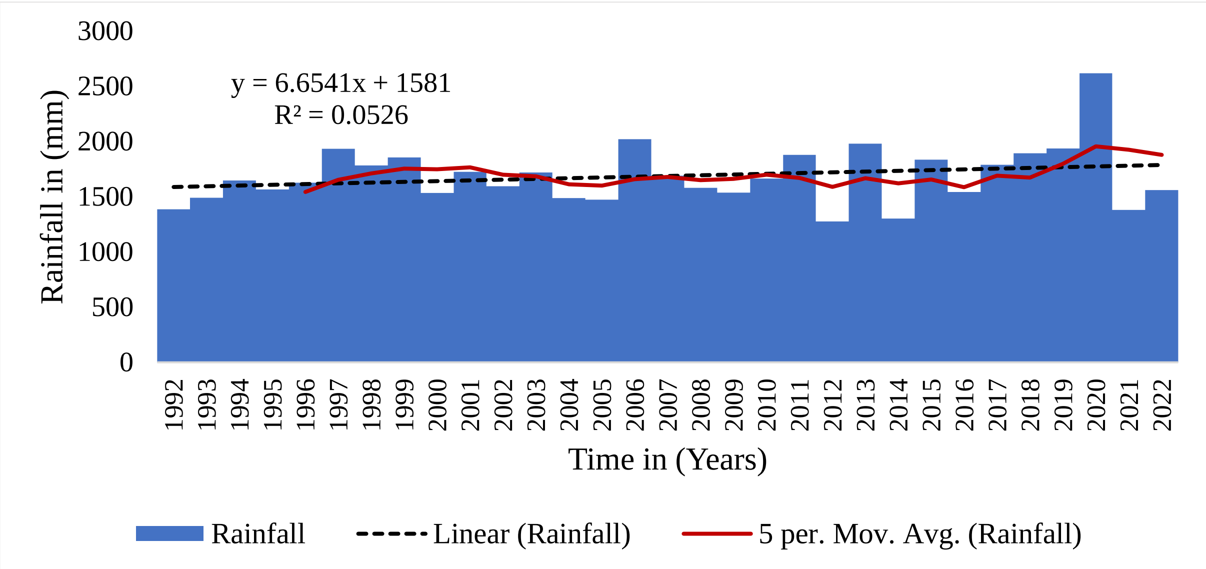
The results in Table 2 showed increased temperature trends across the four seasons. The month of June to August (JJA) season recorded the most significant warming trend $p < 0.0001$, with a Sen's slope of 0.150. The March to May (MAM) and September to November (SON) seasons also showed significantly moderate temperature rise. In contrast, the December to February (DJF) period exhibited a slight upward trend, but this was not statistically significant, with a *p*-value of 0.057.

Rainfall Variability

Results showed rainfall analysis for the past 3 decades in Nandi County. It was noted that in the year 2012, the County received low amounts of precipitation with a total of 1275.8 mm whereas 2020 received the highest rainfall of 2618.6 mm that year. From the trend line y= 6.6541x + 1581, the positive coefficient of the year variable (6.6541) showed a positive linear relationship between the year and rainfall amounts as shown in Figure 3. This meant that rainfall amounts are to increase by approximately 6.6541 units annually these results agreed with a study done by Omasaki and Mokoro, (2023) that rainfall amounts in Nandi County showed an increasing trend. While the positive slope suggested an upward trend, the low R^2 value (R^2 = 0.0526 translating to 5.26%) indicated that the linear relationship with the year does not adequately account for the variability in rainfall amounts.

To test the significance of the increase in rainfall, the Mann-Kendall Trend analysis was employed. The results indicated an increase in rainfall amounts denoted by Sen's slope= 5.618. However, Kendall's Tau= 0.123 showed a weak positive correlation that was not statistically significant at $p \leq 0.341$.

Figure 3: Mean Annual Rainfall from 1992 to 2022



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Despite analysing long-term annual rainfall trends to provide an overview of climatic variability, examining seasonal rainfall patterns offered more detailed insights into how specific wet or dry periods influenced the growth and spread of dodder throughout the year. The study area received a bimodal rainfall regime. March to May (MAM) season is considered a long rainy season, while the September to November (SON) season is characterized by short rains. December to February (DJF) are the drier months with little rainfall, while June to August (JJA) are the coldest months (Kirui *et al*., 2020). The results as recorded in Table 3 showed no significant rainfall trends in all seasons.

Table 3: Mann Kendall Trend Analysis for Seasonal Rainfall from 1992- 2022

Seasons	Mean	Std. dev.	Kendall's Tau	S	*p*-value	Sen's slope	Lower bound (95%)	Upper bound (95%)
DJF	184.981	81.148	0.148	69	0.248	1.825	-1.500	5.357
MAM	556.477	141.282	0.037	17	0.786	1.100	-4.880	7.824
JJA	538.323	107.922	-0.062	-29	0.634	-0.787	-5.643	3.976
SON	407.729	129.338	0.123	57	0.341	3.033	-2.538	10.065

However, it was important to note an increasing rainfall trend during the short rainy season that is, September to November. These findings agreed with a study by Omasaki and Mokoro (2023) that rainfall has been increasing during the short rainy season in Nandi County. Observations of rainfall patterns particularly the JJA seasons showed a downward trend confirmed by a study conducted by Twahirwa *et al*., (2023) that rainfall patterns in the East African region have been greatly affected by the post-ENSO conditions leading to dry spells between June and August.

Farmers' Perception of Climate Variability Impacts on Dodder Infestation

The Intergovernmental Panel on Climate Change (2021), reported that fluctuations in rainfall and temperature impact the agricultural sector. These variations accelerate the thrive of invasive species such as dodder (Wallingford *et al*., 2020; Finch *et al*., 2021). Therefore, studying the nexus of climate variability and dodder will help in employing control strategies by tea farmers. The results are recorded in Table 4.

Table 4: Influence of Temperature and Rainfall on the Intensity of Dodder Occurrence

Occurrence of dodder	Dry season		Cold season		Long rainy season		Short rainy season	
	N	%	N	%	N	%	N	%
Least intensity	4	1.2%	2	0.6%	2	0.6%	6	1.7%
Moderate intensity	240	69.8%	105	30.5%	13	3.8%	326	94.8%
High intensity	100	29.1%	237	68.9%	329	95.6%	12	3.5%
Total	344	100%	344	100%	344	100%	344	100%

A scaling approach was used to analyze responses categorizing dodder intensity into three levels: 1 (least intensive), 2 (moderate), and 3 (very intensive). The scale range (2) was calculated by subtracting the lowest value (1) from the highest (3), and the interval (0.67) was determined by dividing the range by three scale points. The Average scores for each Likert item were computed to quantify perceived intensity as follows: Least intensity average score falling under 1.00 to 1.67, moderate intensity at an interval of 1.68 to 2.34 and high-intensity average score falling at an interval of 2.35 to 3.00. The mean closer to 1.00 showed that the respondents agreed that dodder was the least intensive compared to a mean of 3.00.

Article DOI : https://doi.org/10.37284/ajccrs.4.1.2605

Table 5: The implication of temperature and rainfall on dodder occurrence

	No. of respondents (N)	Mean(μ)	Std. dev.	Implications on the intensity of dodder occurrence
Dry season	344	1.72	0.47	Moderate intensity
Cold season	344	2.68	0.48	High intensity
Long rainy season	344	2.95	0.24	High intensity
Short rainy season	344	1.98	0.23	Moderate intensity

The results in Table 5 indicated that the intensity of dodder occurrence was moderate during dry months and the short rainy season. However, 95.6% of respondents reported a high intensity of dodder occurrence during the long rainy seasons, and 68.9% noted a high intensity during cold seasons. Despite this, respondents were more confident in the assertion that dodder spread is more intense during high rainy seasons than during cold seasons, as reflected by the standard deviations of 0.242 and 0.478, respectively.

It was observed that in the dry and short rainy season, there was moderate intensity in the occurrence of dodder. This was due to water scarcity leading to tea bush stress and hence slowing down the spread of dodder. In cold and long rainy seasons, water availability facilitated the fast growth of tea bushes and leaves that promoted the growth and spread of dodder. However, Chepkirui (2020), and Orwah (2022) found that dodder species are likely to thrive in warmer environments.

Perceived Effects of Dodder on Tea Farming

Parasitic dodder threatens crop production (Dawson *et al*., 1994) resulting in food insecurity globally. Chepkirui (2020), reported that in Kericho County, Kenya, tea (*Camellia Sinensis*) was the most suitable host with 2391 out of the 7300 plant species. In Nandi County, tea is the mainstay however, Mong'o *et al*., (2024) found that dodder has significantly threatened tea farming. Therefore, it was important to assess the perceptions of tea farmers on the effects of dodder on tea. Friedman Test was used to obtain the ranks from the most to least observed effect of dodder on tea.

Table 6: Observed Effects of Dodder on Tea

	Mean	Std. Deviation	Mean Rank	Rank
Lowers tea productivity	4.39	0.83	4.93	VI
Lowers tea quality	4.39	0.82	4.94	V
Lowers tea taste quality	1.03	0.26	1.09	VIII
Interferes with leaf hand plucking	4.90	0.33	6.09	I
Reduces tea bush vigour	4.51	0.64	5.14	IV
Interferes with machine leaf plucking	3.10	1.16	2.73	VII
Lowers quantity of tea sales	4.66	0.59	5.48	III
Increased financial expenditure	4.70	0.55	5.60	II

The results in Table 6 showed that on average, respondents perceived parasitic dodder to have a high negative impact on lowering productivity, tea quality, tea bush vigour, quantity of tea sales, interference with leaf hand plucking, and increase of financial expenditure in management. However, the low mean and standard deviation on respondents' perception of the effect of dodder on lowering tea taste quality suggest a consensus that this aspect was minimally affected. The respondents' perceptions on dodder lowering tea productivity, tea quality, and interfering machine leaf plucking (Std. Dev. 0.83, 0.82, and 1.16 respectively) indicated that there was variability in the opinions of respondents as they had different perceptions on the effects of dodder on said variables. These findings agree with the findings by Masanga *et al*., (2021), Yego *et al*., 2022, and Mong'o *et al*., (2024) that dodder has impacted tea farming incurring economic losses to farmers.

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Figure 4: Tea Bushes Attacked by Dodder

Management of Dodder

Results showed that handpicking dodder twines was the most preferred method to control dodder among respondents (62.6%). The respondents preferred this technique as it effectively reduces dodder spread, especially when the infestation is not severe and targets dodder removal without affecting the entire tea bush.

Table 7: Methods of Dodder Control

Dodder Control Techniques	Mean	Std. Deviation	Mean Rank	Rank
Herbicide application	1.26	0.83	3.22	VI
Handpicking twining	4.05	1.43	6.22	I
Slashing twining	1.35	0.87	3.36	V
Burning twining and infested plants	1.65	1.32	3.65	IV
Burying twining and infested plants	2.48	1.60	4.69	II
Uprooting infested plants	1.26	0.91	3.16	VII
Pruning-infested tea bushes	1.82	1.57	3.70	III

It was observed that 20.1% of the respondents buried the twines detached from the tea bushes to curb further spread. Depending on infestation severity, pruning tea was employed by 18.2% of respondents. Although herbicides such as glyphosate were generally avoided due to their potential to harm tea plants, 3.3% of respondents used them as a control measure. This corresponds to the findings by Chepkirui (2020), that the use of herbicides was not a suitable technique for dodder control.

CONCLUSION

This research found that climate varied in Nandi County from 1992 to 2022, with temperatures showing a slight increase and rainfall displaying minimal and statistically insignificant changes. Climate variability influenced the spread of dodder on tea farms, with increased intensity observed during colder months and long rainy seasons. This pattern is likely due to improved tea bush vitality during periods of higher water availability, which supports dodder growth and survival.

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The study also revealed that parasitic dodder negatively impacts tea farming, severely reducing productivity, tea leaf hand plucking, tea quality, and bush vigour while increasing financial costs in management. These findings concluded that the continued intensification of climatic trends may exacerbate economic and ecological challenges for tea farming, threatening its long-term sustainability.

Therefore, this study recommends further research to examine the effectiveness of different Integrated Pest Management strategies under varying climate conditions. Additionally, the government through research institutions should implement a program to identify and map areas with dodder for ease of monitoring and surveillance of dodder.

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