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Can Natural Farming Help to Combat Climate Variability? A Comparison of Natural and Chemical Farming in Andhra Pradesh, India

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Abstract

A study was conducted to compare the potential of natural farming versus conventional chemical farming to withstand adverse climate effects. The study investigated two cyclones, namely cyclone Pethai and cyclone Titli of 2018, which caused significant damage to Andhra Pradesh's coastal corridor. In addition, the impact of heavy rainfall in 2021 on two different farming systems was studied. The worst-affected Paddy crop regions where these cyclones caused severe damage were surveyed. Multiple linear regression was utilized to investigate predictors including crop damage, wind damage, submergence, and yield loss in these two agricultural systems during these two cyclonic and heavy rainfall events. The study indicated that natural farming practices were more resilient to climate variability than conventional chemical farming techniques. The study showed a statistically significant difference ($p < 0.001$) between these two farming systems in terms of damage caused due to climate variabilities.

Keywords

Natural Farming, Climate Resilience, Cyclones, Heavy Rainfall

1. Introduction

Climate change in India has had multiple impacts on Indian farmers and has placed them in an even more vulnerable position. Changes in weather conditions have a significant impact on crop cycles and eventually, the way crops are grown, and the food is produced. The periodic cyclones and floods in the coastal corridor of India are a common phenomenon for coastal farmers, but the frequency has increased dramatically in recent years [1]. UNFAO estimates that the agricultural sector absorbs 22% of the damage in developing countries after natural disasters [2]. According to UNFAO, a total damage from cyclones from 2003-2013 in Asia was estimated to be around $70 billion, with crops and livestock being the hardest hit. Similarly, a report by a group of scientists from the **Potsdam Institute for Climate Impact Research and Climate Analytics** for the World Bank suggests that the periodicity of extreme monsoons, which occurs every 100 years, is likely to occur in India every ten years, and that would be responsible for a significant decline in crop yields [3]. India is a country that is highly prone to floods and cyclones, having a coastal corridor of 7516 km that has frequent occurrences of cyclones and floods. The available dataset on cyclonic activity in India from 1891 to 2000 reveals that the country experienced a total of about 308 cyclones over this period, with 103 of them classified as severe [4]. Among the 103 severe cyclones recorded from 1999-2017, nine specific storms, such as the Odisha cyclone, cyclone Dhyan, cyclone Nilam, cyclone Helen, cyclone Phaillin, cyclone Hudhud, cyclone Varadh, and cyclone Ockhi, have been identified to have caused significant damage [5]. Nevertheless, all coastal areas are affected by cyclones; the east coast is more prone to cyclones compared to the west coast [6]. The Indian Meteorological Department reports an alarming 11% increase in the number of cyclones in the Arabian Sea and Bay of Bengal over the past five years, with catastrophic implications for India's global warming [7].

1.1. Farmers' Adaptations to Climate Change

There is ample evidence in the literature that farmers are attempting to diversify their farming systems and sources of income to adapt to these changes. Family farms react more strongly to these extreme climatic events than individual farms [8] [9]. Farmers are changing agricultural practices and adapting to climatic variability by shifting to crop diversity, moving to multiple cropping, changing land management techniques, and using flood-resistant cultivars [10]. These are specific coping strategies for dealing with the tropical cyclones in India [11]. In literature, climate-smart agricultural practices are more likely to be suggested to deal with climate catastrophes [12]. It has been shown that changing certain agricultural practices can reduce anthropogenic greenhouse gas emissions [13]. Furthermore, great importance is ascribed to "crop diversification" as a long-term adaptation strategy that protects against severe climate shocks [14]. Organic farming has emerged as an alternative, viable social moment that prioritizes socio-environmental resilience [15] [16]. Globally, crop diversity per unit of arable land is declining and monocultures, mainly soybean and maize, contribute the majority of cropping systems [17]. Diversification, especially crop biodiversity such as polycultures, mixed cropping, and agroforestry systems, is essential to minimise crop damage and be more resilient than other conventional farming methods. Agroecology is widely discussed as an alternative system of agricultural production and various practices; the principles of agroecology will make agricultural systems more resilient to climate change. Agroecology can help restore resilience through its practices and principles [18]. These practices are commonly promoted to address farmers' vulnerability to climate change. Natural farming being an agroecology approach is widely promoted on a large scale in Andhra Pradesh, a south-eastern Indian state. It is called Andhra Pradesh Community Managed Natural Farming (APCNF). There is a large-scale adoption of natural farming by the farmers in the state. The focus is on farming in harmony with nature by mimicking nature through the adoption of polyculture, cover cropping, and regenerative farming. APCNF is a holistic land management practice that harnesses the power of plant photosynthesis to close the carbon cycle and promote soil health, crop resilience, and nutrient diversity.

1.2. The Principles and Philosophy of Natural Farming

Natural farming largely depends on nine general principles that support "farming in harmony with nature". Each principle is interconnected. Eight of these nine principles promote natural farming, and the last says "no" to synthetic chemicals.

1.2.1. Covering the Soil for 365 Days

The fundamental concept of natural farming is maintaining 365-day green cover, which improves microbial diversity by enabling living roots to live in the soil [19]. The use of a multi-cropping system throughout the year has been shown to enhance soil health by facilitating the release of root exudates into the soil through a combination of diversified and vigorous root activity [20]. Root exudates have a crucial role in promoting the proliferation of the soil microbiome, hence initiating the activation of the soil food web. The enhancement of the soil biome results in changes to the physical and chemical characteristics of the soil. This crucial principle shows that plants replenish soil by managing water and nutrient cycles. Covering crops for 365 days has been found to not only enhance soil fertility but also contribute to reducing greenhouse gas (GHG) emissions from agricultural activities by around 10 percent [21] [22].

1.2.2. Enhancing Crop Biodiversity

Enhancing crop biodiversity is the second important natural farming principle. Plants manufacture food through photosynthesis and nourish the soil by allocating 60% of the food through their root systems. The remaining 40% of plant food is used for growth and metabolism. Each plant species has a specific group of dormant soil microorganisms associated with them [23]. Every plant sends some chemical signals to activate the soil's microorganisms when it releases food into the soil [24]. The microbes associated with that plant species get activated and other soil plant microorganisms will remain silent. The plant needs nutrients from active microbes. For enhanced soil health, crop diversification must be increased to activate all inactive microbes. Increased crop biodiversity increases the proliferation of more bacteria that are associated with different species of the plant. Increased crop diversification activates soil microbes, maximising plant nutrient supply [25]. A crop mix of millets, pulses, oil seeds, vegetables, creepers, and forbs may increase microbial diversity. Crop diversity above ground increases soil biodiversity below ground. Higher crop biodiversity increases soil microbial activity and plant nutrition transport, improving yield quality. Integrating trees into farms activates microbes in deeper soil layers, improving soil microbial diversity. Regulation of atmospheric temperatures and the monsoon cycle by trees.

1.2.3. Low or Minimal Tillage

Low or minimal tillage, is the third important principle in natural farming which reduces soil erosion, prevents soil organic carbon loss, improves soil structure, and boosts crop yields [26] [27]. Wind, water, and tillage practices result in 15 tonnes of topsoil erosion per hectare in India each year [28].

1.2.4. Crop Residue Mulching

The fourth principle involves mulching and crop residue to add organic matter to the soil. This technique increases soil organic carbon. This principle states that applying crop residue (mulch) to the soil can prevent moisture loss, lower soil temperature, and give plants a limited nutritional supply. However, live mulch (living roots covering the soil) is always preferable to crop mulch.

1.2.5. Use of Farmers' Own Seed or Local Seeds

The fifth natural farming principle is using the farmers' own seed or local seed. Local climate-resilient seeds have a seed core microbiome with various microbial communities in their tissues (endophytes) and surfaces that are passed down from generation to generation [29]. These seed core microbiomes improve food quality, taste, climate change adaptation, and plant health. Seeds, roots, stems, branches, leaves, and fruits contain microbes. Treating the seed with Beejamrutham, a biostimulant that will signal the seed's microbiome and a cross-talk will happen between seed microbiome with inactive microbes, to activate soil microbes. These microbes help plants at various crop stages get nutrients.

1.2.6. Integrating Animals into the Farming

The sixth principle focuses on integrating animals into farming as much as possible. This emphasises the importance of animals in agricultural systems. The integration of crops and animals is frequently regarded as a viable approach to achieving sustainable agricultural production due to the concurrent enhancement of organic matter and nitrogen cycling. The primary source of organic matter and nutrients on farms is the residue left behind from various crops. The integration of livestock is advantageous because of the significant role animals play as capital assets for security, additional cash revenue, and nutrient fluxes.

1.2.7. Use of Biostimulants

The seventh principle refers to the use of biostimulants such as solid and liquid Jeevamrutham, egg amino acids, and fish amino acids. These biostimulants are derived from natural sources and should not be considered as substitutes for fertilizers. They are commonly referred to as "biological switches" due to their ability to activate dormant soil microbes by initiating their proliferation and facilitating metabolic processes that support microbial growth, resulting in the addition of nutrients to plants [30]. Plants could adapt to both abiotic and biotic stresses due to their symbiotic relationship with numerous microbes [31].

1.2.8. Need Based Pest Management

The eighth principle refers to pest control, wherein it is seen that an increase in crop diversity is associated with a decrease in pest occurrence. However, in instances where there is a rise in insect population, the utilization of preventive pest management techniques such as decoctions and mechanical operations may serve as interim measures.

1.2.9. No Synthetic Chemical Use

Natural farming strictly says no to the use of synthetic chemicals in any form, hence severely forbidding their usage. This philosophy is accepted as the last principle of natural farming.

All these practices and principles of natural farming help make the soil healthier and more resistant to problems like drought, storms, and heavy rain. A review of the literature shows that there is not much published evidence about natural farming practices leading to resilience to climate variability. This study looked at how floods, cyclones, and heavy rains affect natural farming compared to a monoculture-based conventional chemical farming system. It also tried to figure out how effective natural farming is against floods, cyclones, and heavy rains compared to conventional chemical agriculture in Andhra Pradesh in three different catastrophic events. To this end, it is crucial to support the argument with robust empirical evidence, comprising numerous indicators. The hypothesis posited in this study was that natural farming, as an agroecological approach, shows greater resilience to climate variability and cyclonic events compared to conventional chemical farming. The study investigated the effects of two prominent cyclones, namely cyclone Titli and cyclone Pethai, which happened in 2018, on two different farming systems, namely natural farming, and conventional chemical farming [32] [33]. Similarly, data was gathered regarding the effects of intense precipitation on the two farming systems during a two-week period of high rainfall in Andhra Pradesh in November 2021. The Titli cyclone caused a greater extent of damage in comparison to the other cyclone. The districts of Srikakulam and Vizianagaram in the state of Andhra Pradesh saw severe impacts from the Titli cyclone, resulting in substantial agricultural losses [34]. According to the data, the cyclone resulted in the devastation of around 8800 hectares of vegetable crops and 1352 hectares of paddy crops over three blocks in Srikakulam. In December 2018, Andhra Pradesh experienced the impact of cyclone Pethai, resulting in substantial agricultural losses. A significant damage of paddy fields measuring 2179 hectares and an additional 30 hectares of horticulture crops incurred substantial damage.

2. Materials and Methods

To be able to assess the relative performance of natural farming and chemical farming in alleviating the impacts of climatic variations, a comprehensive investigation was conducted on fields showing different levels of damage. The researchers carried out face-to-face interviews with farmers who had encountered crop loss on their agricultural lands to acquire an in-depth understanding of the various repercussions. The study adopted a **matched pair design** and employing **Purposive Mixed Probability sampling** [35] [36]. Purposive mixed probability sampling, which combines both quantitative and qualitative traits [37]. The objective of this study was to identify and collect samples from places that have seen significant impacts from cyclones and severe rains. The quantity of representative samples was insufficient, necessitating the inclusion of both quantitative and qualitative judgments. This sample method was deemed advantageous for the objective at hand, since it allows the researcher to gain insight into the comprehensive shifts that may occur when transitioning from quantitative to qualitative techniques throughout the study process. The sample methodology utilized in this study was designed to encompass both qualitative and quantitative characteristics that were associated with prevalent catastrophic events within the given environment. The study opted to choose farms from the dominant crop in the area where the cyclone and heavy rains have severe affect, with the coexistence of both natural and conventional chemical farming methods side by side. The research primarily studied areas exposed to the effects of cyclones or heavy rainfall during adverse climate conditions, particularly in the aftermath of the events. These characteristics included the existence of identical crops and soils as well as the use of different farming methods. The farms chosen for the comparative research over these two adverse climatic occurrences (cyclones) were chosen explicitly during the aftermath of the cyclones in north-coastal Andhra Pradesh, as the cyclones studied had affected the north-coastal districts of Andhra Pradesh. For the study on heavy rainfall events, it was spread across all districts of Andhra Pradesh. The data in the following table (**Table 1**) provides information about the year in which cyclones occurred, the damaged crops, and the number of comparable samples selected based on the region affected. The selection of the Paddy as the focus of study was based on the apparent visibility of damage indicators and the convenient accessibility of information gathering from farmers.

After the end of cyclone Pethai, there was significant damage to the paddy crop in Srikakulam and Vizianagaram districts. A total of 48 pairs of farms were selected for our study in these areas. In a similar vein, after the occurrence of the

Table 1. Comparative samples selected for the study.

S. No	Cyclone/Heavy rain	Year	Crops	APCNF	Chemical	Districts
1	Pethai cyclone	2018	Paddy	48	48	Srikakulam, Vizianagaram
2	Titli cyclone	2018	Paddy	40	40	Srikakulam, Vizianagaram
3	Heavy rains	2021	Paddy	30	30	All districts

Titli cyclone, we were able to arrive at a set of 40 sample pairs. In assessing the consequences of heavy rains, data was collected from 30 farm pairs across Andhra Pradesh. Farmers using both natural farming and conventional chemical farming were asked to provide their ratings on a Likert scale on scale of 1 to 5. According to the scale utilized in this study, a numerical value of "one" is associated with a classification of "very low" in terms of the extent of damage observed. Similarly, a numerical value of "two" corresponds to a classification of a "low" level of damage. In a similar vein, it is noteworthy to mention that a numerical rating of "three" corresponds to a level of damage categorized as "medium. Furthermore, a rating of "four" is indicative of a level of damage classified as "high," while a rating of "five" signifies a level of damage characterized as "very high." regarding the extent of damage caused by various factors such as wind damage, submergence, lodging, and the predictable decrease in crop yields after the incident. In a similar vein, field observations were made to determine the length of the roots, and accompanying photographs were taken to provide a visual representation of the post-event conditions.

Statistical Analysis

The data collected was analysed using the multiple linear regression model in SPSS software. The dependent variable was the farming system since the objective was to ascertain the differences in tolerance levels between these two systems of farming in relation to climatic variabilities. The study examined various independent variables, such as damage percentage, lodging, wind damage, and submergence. The data about the length of the roots and the percentage of recovery was also recorded. The research used an independent t-test as well to analyse the statistical significance between two independent variables.

3. Results

3.1. Cyclone Pethai

To determine if various farming systems can influence climate variability on predictors such as damage percentage, lodging, wind damage, and submergence, a multiple linear regression in SPSS was used. The results from the table (Table 2) show a R^2 value of 82.2 percent of the variance was observed in the farming systems (natural versus chemical), explained by the predictors yield decline,

Table 2. Multiple Linear regression model of cyclone Pethai.

Model	R	R^2	Adj R^2	F change	df1	df2	Sig. F change	Durbin-Watson
1	0.907	0.822	0.810	68.538	6	89	<0.001	1.632

Predictors: (Constant), Drop in yields, Stage of the crop, Submergence, Lodging, Wind damage, Dependent Variable: Farming system.

stage of crop, submergence, lodging, wind damage, and total ($F(6, 89) = (62.74)$, $p < 0.001$). That indicates a significant difference between the natural farming system and the chemical farming with regards to the drop in yields, crop stage, submergence, lodging, and wind damage caused by cyclone Pethai in 2018.

The F ratio in the ANOVA table (**Table 3**) tests whether the overall regression model fits the data well. The table shows that the independent variables such as yield decline, crop stage, submergence, lodging, and wind damage statistically significantly predict the dependent variable (farming systems): $F(5, 90) = 62.741$, $p < 0.001$ (*i.e.*, the regression model fits the data well). After looking at the effects of each of the predictors listed in **Table 3**, such as crop stage, wind damage, submergence levels, lodging, the percentage of damage, and a drop in yields caused by cyclone Pethai, it was clear that, except for crop stage, all the other predictors show a positive correlation with changes in farming systems.

The results show that the stage of the crop ($\beta = -0.160$, $t = -3.166$, $p = 0.002$) has a significant influence on the farming system. There was less influence of cyclones on old-age crops when compared to younger-age crops. Furthermore, the statistical analysis reveals a significant difference between natural and conventional chemical farms in relation to stage of the crop. The influence of predictors like wind damage ($\beta = 0.023$, $t = 1.067$, $p = 0.289$) was not significant (**Table 4**).

Similarly, the predictor submergence did not have significant influence on the farming system ($\beta = 0.062$, $t = 0.301$, $p = 0.764$). The other predictors like lodging ($\beta = 0.138$, $t = 2.441$, $p = 0.017$), percentage of damage ($\beta = 0.417$, $t = 4.474$, $p < 0.001$) and drop in yields ($\beta = 0.404$, $t = 4.501$, $p = 0.001$) have significant variation in the farming systems due to the Pethai cyclone.

A statistical analysis using an independent t-test was conducted to examine the significant difference in the effects of cyclone between natural and chemical farms. A statistically significant difference was observed between natural and chemical farms in relation to the effects of cyclone Pethai. Natural farming exhibited a negative impact on the cyclone Pethai impact in comparison to conventional chemical-based farming practices. The graph depicted in **Figure 1** illustrates the effects of cyclone Pethai on the variables associated with natural and chemical farming practices. The incidence of wind damage in natural farming was found to be 9.56 percent, whereas in chemical farming it was found to be 17.37 percent ($p = 0.001$). In a similar vein, it was observed that a mere 4.93 percent of paddy fields were drowned during the cyclone; however, the proportion of chemical fields affected was notably higher at 9.35 percent, with a statistically significant p-value of less than 0.001. Comparatively, it was observed that

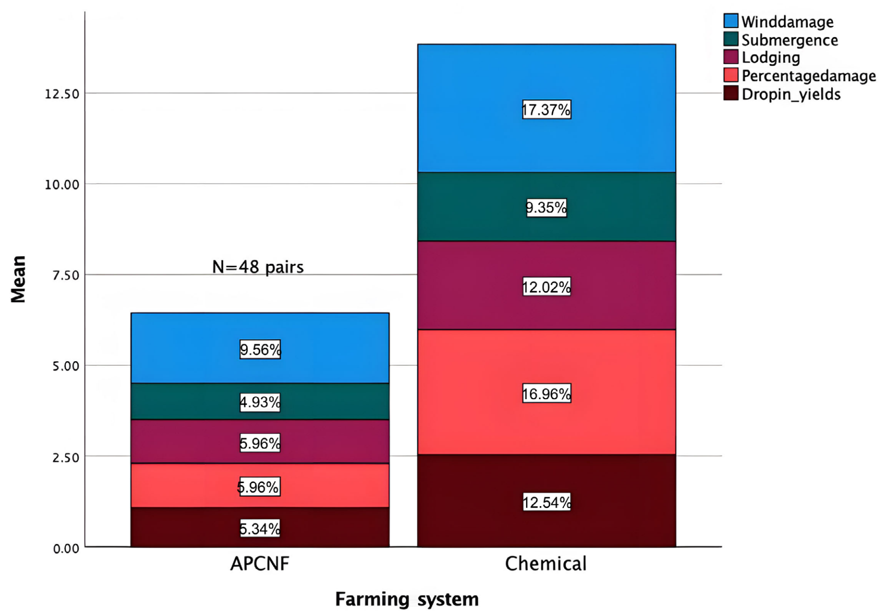

Figure 1. Impact of cyclone Pethai on natural versus chemical farming.

Table 3. ANOVA[a] results of cyclone Pethai.

Model	Sum of Squares		df	Mean Square	F	Sig.
	Regression	18.650	5	3.730	62.741	<0.001[b]
1	Residual	5.350	90	0.059		
	Total	24.000	95			

[a]Dependent Variable: Farming system. [b]Predictors: (Constant), Yield loss, wind damage, submergence, lodging.

Table 4. Coefficients of regression for Pethai.

Model	B	Std. Error	β	t	Sig.
(Constant)	0.887	0.133		6.657	<0.001
Stage of the crop	−0.167	0.053	−0.160	−3.166	0.002
Wind damage	0.011	0.035	0.023	0.301	0.764
Submergence	0.035	0.033	0.062	1.067	0.289
Lodging	0.064	0.026	0.138	2.441	0.017
Percent damage	0.160	0.034	0.417	4.745	<0.001
Drop in yields	0.232	0.052	0.404	4.501	<0.001

the lodging prevalence in natural farming fields was significantly lower (5.96 percent) compared to chemical fields (12.2 percent), with a statistically significant p-value of less than 0.001. Additionally, a significant difference in the percentage of damage was found between natural farming fields (5.96 percent) and chemical fields (16.96 percent), with a p-value of 0.005. The observed yield loss in natural farming fields was found to be relatively low at 5.34 percent; however, in chemical farming fields, it was recorded at 12.5 percent. This difference in yield loss between the two farming methods was statistically significant, as indicated by a p-value of less than 0.001.

The graph depicted in Figure 2 shows a comparison of root length, measured in centimeters, between natural farming and chemical farming. The root length in natural farming was 13.30 centimeters, but it was lower in conventional chemical farms (7.84 cm). The average recovery percentage in natural farming after the cyclone was 64.98 percent, while in conventional chemical farming, the average recovery percentage was 35.02 percent. The data reported suggests that there could be a positive correlation between root length and the ability of crops in natural farming to remain intact in the soil and resist damage caused by cyclones. The reduced length of roots in conventional chemical farms was found to be a contributing factor to the occurrence of cyclonic damage.

3.2. Titil Cyclone

In October 2018, the state of Andhra Pradesh experienced significant devastation from cyclone Titli. The study examined the impact of the cyclone on the paddy crop in the coastal district shortly after its occurrence. The study hypothesises that the impact of cyclone Titli on the two farming systems studied may be different. The study examined farming systems (both natural and conventional chemical) as the dependent variable, whereas yield loss, wind damage, flooding, and lodging resulting from the cyclone's impact on the crops were considered as predictors. The results were analysed using multiple linear regression in SPSS. The results shown in Table 5 highlight that a significant proportion of the variance (96.5 percent, as indicated by the R^2 value) in the farming systems (natural versus chemical) can be accounted for by the predictors of yield loss, wind damage, submergence, lodging, wind damage. The statistical analysis ($F(4, 75) = 513.91$, $p < 0.001$) demonstrated a strong relationship between these predictors and the observed variance. Additionally, the Durbin-Watson value of 2.283 suggests that the data exhibits a moderate level of autocorrelation.

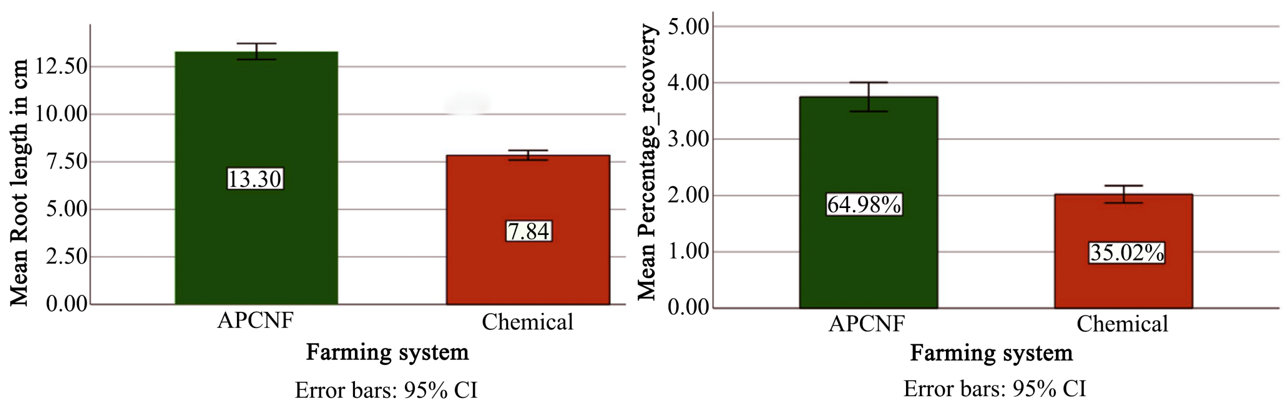

Figure 2. Root length and recovery percentage differences in Pethai cyclone affected crops.

Table 5. Model summary of Titili cyclone regression.

Model	R	R^2	Adj R^2	F change	df1	df2	Sig. F change	Durbin Watson
1	0.982	0.965	0.967	513.91	4	75	<0.001	2.283

Predictors: (Constant), Yield loss, wind damage, submergence, lodging. Dependent Variable: Farming system.

The findings derived from the analysis of variance (ANOVA) in the regression analysis indicate that the regression model exhibited a satisfactory level of fit for the given dataset. The results demonstrate that the independent variables, namely yield loss, wind damage, submergence, and lodging, exhibit a statistically significant predictive relationship with the dependent variable farming systems as indicated by the equation ($F(4, 75) = 513.91$, $p < 0.001$). This indicates that the regression model effectively fits the observed data. The coefficients from the tabulated results (**Table 6**) show that lodging of crops on the two comparable farms had a significant positive impact ($\beta = 0.109$, $t = 5.225$, $p < 0.001$). It indicates that there was a significant difference in crop lodging between natural farming and chemical farming, with lodging serving as a predictor variable that exerted a substantial influence on the farming system. Moreover, the findings obtained through the regression analysis coefficients reveal a statistically significant difference between natural and chemical farms about crop submergence in the aftermath of the Titli cyclone. The predictor variable, crop submergence ($\beta = -0.088$, $t = 4.659$, $p < 0.001$), had a significant impact with a high level of statistical significance. The farming system had substantial effects from wind damage resulting from the Titli cyclone, as reflected by the statistically significant effect ($\beta = 0.107$, $t = 5.757$, $p < 0.001$). Yield loss was a significant predictor with an evident impact on farming systems in the aftermath of the Titli cyclone ($\beta = 0.038$, $t = 2.144$, $p = 0.035$).

The graph in **Figure 3** illustrates the contrastive effects of cyclone Titli on farming systems, specifically natural farming, and conventional chemical farming. It is evident that there was a considerable difference in the impacts experienced by these two farming systems. The cyclone Titli showed very little impact on the various indicators associated with natural farming. The graph depicted in **Figure 3** indicates the proportion of lodging in natural farming was 5.60 percent, but it surpassed 21.44 percent in conventional chemical farms. The submergence level of fields was low in natural farming fields (5.97 percent), and it was 19.73 percent in conventional chemical fields. The damage caused by high winds was 6.33 percent, and it was high in conventional chemical farms (19.61 percent). The yield loss was only 6.09 percent in natural farming fields, whereas the yield loss in conventional chemical fields was 15.23 percent.

The results of this study indicate that natural farming showed greater resilience to cyclone Titli across all indicators when compared to chemical farming. Moreover, there was a statistically significant difference in the effects of cyclones between the two farming systems. The crops cultivated using natural farming

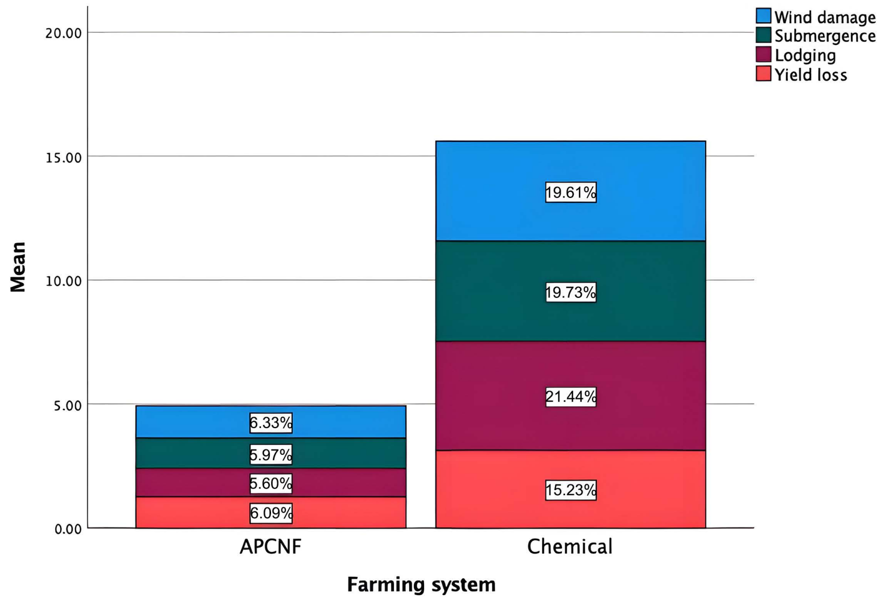

Figure 3. Titli cyclone impacts in natural farming versus chemical farms.

Table 6. Regression coefficients from Titli cyclone.

Coefficients[a]						
Model		B	Std. Error	β	t	Sig.
	(Constant)	0.598	0.025		23.581	<0.001
	Lodging	0.109	0.021	0.368	5.225	<0.001
1	Submergence	0.088	0.019	0.266	4.659	<0.001
	Wind damage	0.107	0.019	0.309	5.757	<0.001
	Yield loss	0.038	0.018	0.084	2.144	0.035

[a]Dependent variable: Farming system.

methods remained undamaged, while the crops grown in fields using conventional chemical farming methods were affected by lodging caused by wind damage. The empirical results in terms of recovery levels and root length as illustrated in the figure below (Figure 4) after the Titli cyclone suggest that the crop had a rapid recovery rate in the context of natural farming, with a prominent recovery percentage rated from "high to very high (4 to 5)" on the Likert scale, but chemical farming reflected a considerably lower rate of recovery. The root length comparison of the natural versus chemical farms after the Titli cyclone, revealed that the average root length was higher in natural farming plants (18.06 cm) when compared to chemical farming, where the average root length was only 15.12 centimeters.

3.3. Heavy Rains Impact

During the month of November 2021, several districts of Andhra Pradesh experienced heavy rainfall for a prolonged period, resulting in significant rainfall for

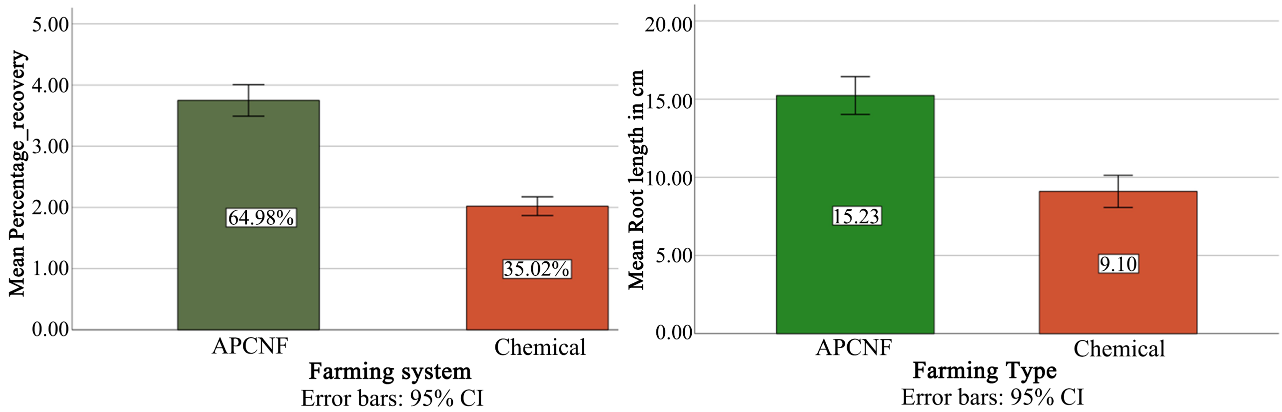

Figure 4. The recovery percentage and root length comparison after Titli cycone.

almost 20 consecutive days. During that period, data was collected in all districts of Andhra Pradesh by selecting 30 pairs of comparable paddy farms (both natural and conventional chemical farms). The data were analysed using multiple linear regression analysis, with a focus on testing the hypothesis that natural farming has a greater tolerance for extreme rainfall events compared to chemical farming. The dependent variable studied was farming systems, while the variables used as predictors were crop damage, wind damage, submergence, and lodging. The graphic shown in Figure 5 reveals that the proportion of lodging in natural farming was 4.74 percent, while in conventional chemical farms there was a significantly higher proportion of lodging at 46.91 percent. The conventional chemical farms experienced significant crop loss (34.89 percent) due to excessive rainfall, whereas natural farming exhibited minimal crop damage (5.89 percent). Due to the heavy rains, there was minimal submergence and wind damage on both farms.

The evaluation of multiple linear regression yielded a model summary, which showed an adjusted R-square value of 0.982. It means that 98.2 percent of the variability in the farming systems could be explained by the predictors: lodging, crop damage, submergence, and wind damage. The overall model was found to be statistically significant ($F(4, 55) = 825.897$, $p < 0.001$). Added to that, the Durbin-Watson statistic of 2.103 was computed, indicating a proximity to the optimal value of 2.

The analysis of variance (ANOVA) findings for the heavy rainfall regression study (Table 7) demonstrated that the regression model was adequate to explain the observed data. The findings of the study indicated a statistically significant predictive relationship between the independent variables, namely crop loss, wind damage, submergence, and lodging, and the dependent variable, agricultural systems. The statistical analysis ($F(4, 55) = 825.897$, $p < 0.001$) provided evidence that the regression model well reflects the observed patterns within the dataset.

The regression coefficients (Table 8) related to heavy rain impacts shown a statistically significant difference between natural and conventional chemical

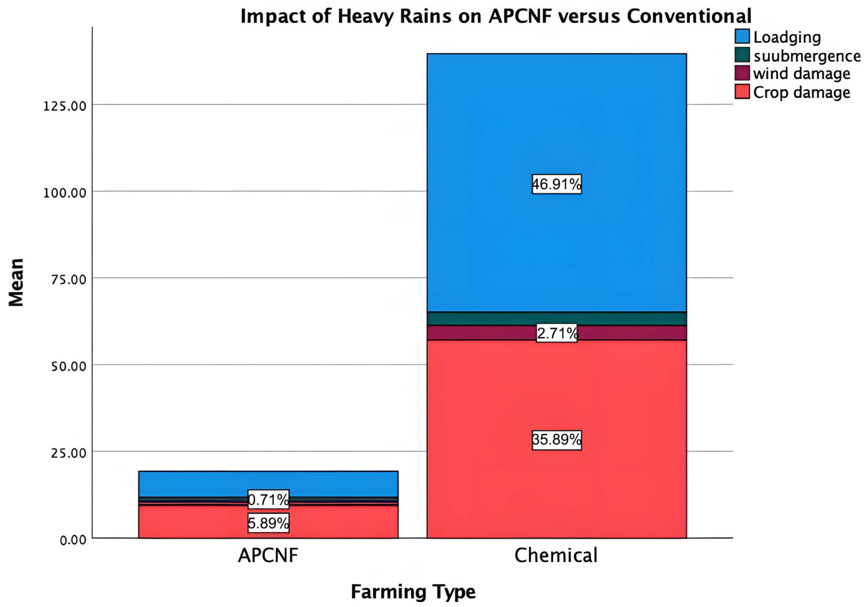

Figure 5. Comparison of damage in natural and chemical farms due to heavy rains.

Table 7. ANOVA[a] for heavy rain impact.

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	14.754	4	3.689	825.897	<0.001[b]
1	Residual	0.246	55	0.004		
	Total	15.000	59			

[a]Dependent Variable: Farming system. [b]Predictors: (Constant), Crop damage, wind damage, submergence, lodging.

Table 8. Regression coefficients[a] from heavy rain impacts.

Coefficients[a]						
	Model	B	Std. Error	β	t	Sig.
	(Constant)	0.790	0.021		37.694	<0.001
	Crop damage	0.002	0.000	0.149	5.725	<0.001
1	Wind damage	0.059	0.014	0.193	4.150	<0.001
	Submergence	0.054	0.016	0.152	3.294	<0.002
	Lodging	0.008	0.001	0.553	10.913	<0.001

[a]Dependent variable: Farming system.

farms about crop damage. The impact of the predictor variable, specifically crop damage ($\beta = 0.149$, $t = 5.725$, $p < 0.001$), exhibited a high level of statistical significance. The impact of wind damage after heavy rains in 2021 had a significant effect on the farming system, as seen by the statistically significant effect (β =

0.193, $t = 4.150$, $p < 0.001$) on the farming systems. The heavy rains have caused a significant impact in 2021 causing submerge of farming systems ($\beta = 0.152$, $t = 3.294$, $p = 0.002$). In the same way, there was considerable impact of heavy rains due to which there was severe lodging of the crops was observed ($\beta = 0.553$, $t = 10.913$, $p < 0.00$).

Data about the root length, as illustrated in Figure 6, show the comparison of root length in natural farming and conventional chemical farming due to heavy rains. There was a significant difference in the root length between these two farming systems. The root length in natural farming was 15.23 centimeters, but the root length in conventional chemical farming was 9.10 centimeters. The results of an independent t-test, which aimed to compare the effects of heavy rainfall on natural farming and chemical farming across many variables, are presented below. To ascertain if there was a difference in ***crop lodging*** between natural and chemical farming, an independent-samples t-test was performed. The findings showed a significant difference between chemical farming (M = 74.53, $SD = 10.13$) and natural farming (M = 7.53, $SD = 2.64$) and represented as [(t (58, 32.94) = −35.017, $p < 0.001$). The mean ***crop damage*** in natural farming was 9.36, with a standard deviation of 8.43, whereas in chemical farming it was 57.03, with an SD of 24.15 (t (58, 50.25) = −10.203, $p < 0.001$). In natural farming, the average ***wind damage*** was 1.23 and the standard deviation was 0.430; in chemical farming, it was 4.3 and the standard deviation was 0.65: [(t (58, 50.25) = −21.520, $p < 0.001$). The mean of ***submergence*** in chemical farming ($M = 3.76$, $SD = 0.626$) and natural farming ($M = 1.13$, $SD = 0.34$), respectively, and represented as [(t (58, 45.18) = −20.167, $p < 0.001$)]. The mean values of ***wind damage*** in conventional farming ($M = 1.23$, $SD = 0.43$) and chemical farming ($M = 4.30$, $SD = 0.651$) and hence the equation was [(t (58, 50.25) = −21.520, $p < 0.001$)].

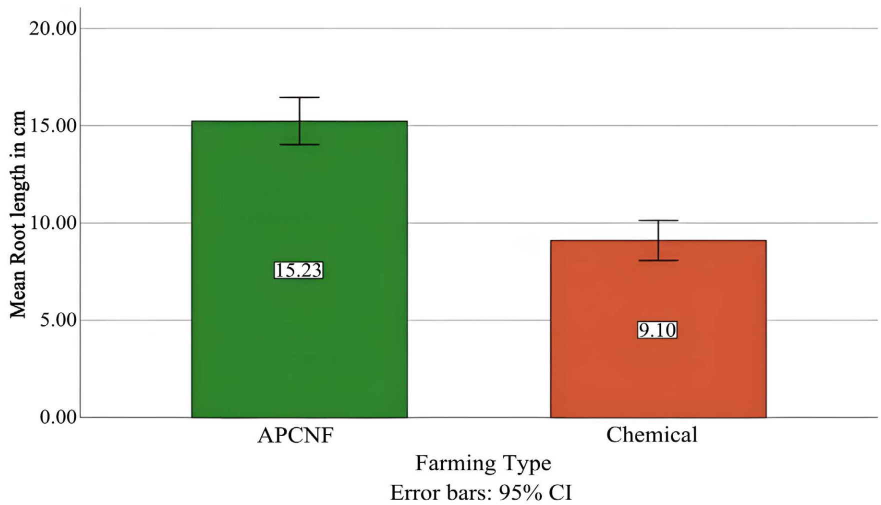

Figure 6. Differences in root length in APCNF versus Chemical farm in heavy rains affected crops.

3.4. Comparative Case Studies of Climate Resilience from the Field

The image below (**Figure 7**) depicts the effects of heavy rain on nearby fields, notably the juxtaposed natural farming field and conventional chemical farming field. Mr. Sanjeev Rayudu was the one who practiced natural farming, while Mr. Veladu was the person who practiced chemical farming. Both individuals were neighbours who lived in the Kurnool district village of Ahobilam. They grew an identical rice type and then transplanted it on a precise date, August 24, 2021. The paddy variety grown in these farms was NDLR-7. This instance shows that the APCNF field was unaffected, but the chemical field suffered considerable lodging.

The photograph presented in **Figure 8** features two neighbouring farmers, namely Mr. Venna Sambasiva Rao on the left and Mr. Venna Sitaramaiah on the right. Mr. Sambasiva Rao was known for his faithfulness to natural farming methods, while Mr. Sitaramaiah was chosen to use chemical farming methods. Both individuals were residents of the village of Polavaram, which is in the Krishna

Figure 7. Crop lodging in APCNF versus chemical farms.

Figure 8. Comparison impact of heavy rains in APCNF and chemical farms.

district of Andhra Pradesh in the coastline region. Both farmers planted the same rice variety (MTU-7029) on the same day. However, due to the heavy rainfall, the natural farming crop remained unaffected, but the chemical field experienced significant damage owing to crop lodging and submergence.

4. Discussion and Conclusions

This study explores the potential effects of natural farming on reducing the adverse effects of climate variability. Particularly, it compares two farming systems, natural farming, and chemical farming, using data from two sequential cyclonic events in 2018 and one heavy rainfall event in 2021 in the state of Andhra Pradesh. The findings of the study clearly suggest that natural farming exhibits considerable potential to tolerate the effects of climatic variabilities when compared to chemical farming. While the data from the literature suggests that alternative agricultural practices, particularly organic farming, might cope with climatic variability [38], there is not much research on the capacity of natural farming to withstand the negative impacts of such variability. This study aims to address a current gap in the literature by examining the potential of natural farming as a novel agricultural technique that can reduce the harmful effects of climate change and enhance resilience to extreme weather events such as cyclones and high rainfall. The results of cyclone Pethai and cyclone Titli in 2018 and heavy rains over a period of 20 days in 2021 have clearly demonstrated the resilience of natural farming over chemical farming methods. In all three events, the dependent variable was the farming system, and the predictors were by and large the same. In the case of all three events, the results have substantially supported our hypothesis that natural farming had greater potential to lower the negative impacts of climate vagaries such as damage due to heavy winds, submergence, crop lodging, and yield loss. In the case of cyclone Pethai, predictors like wind damage and submergence were not significant. However the other predictors, like crop lodging, drop in yields, damage levels, and stage of the crop, were highly significant. The older the stage of the crop, the lesser the damage. The stage of the crop played an important role.

The response of natural farming to climate variability was compared to that of chemical farming approaches. Paddy was chosen for this study in all three cases because it's the principal crop cultivated in the coastal districts of Andhra Pradesh, which are particularly prone to cyclones and excessive rainfall. The incentive for adoption of natural farming practices lies in their ability to reduce soil compaction, enhance soil porosity, and improve water penetration. This attribute may contribute to natural farming's resilience in the face of climate variability. Previous research conducted on natural farming fields has shown that increased infiltration rates in such regions can effectively drain surplus water resulting from cyclones and floods [39].

These findings support the outcome of previous studies on natural farming [40] [41]. The findings of these studies suggest that there will be an increase in earthworm population in natural farming, along with an increase in water holding capacity, porosity, infiltration, and flood and cyclonic impacts [42]. The major reason for the tolerance to climatic variations is the use of natural farming practices such as the application of bio-stimulants, the application of mulch, and the promotion of biodiversity in the cropping system [43]. These findings support the claim that various studies done on changes in root morphology and root-shoot ratio have a positive impact on adverse climatic conditions [44]. The analysis of our data indicates a significant increase in root length, which plays a significant role in maintaining the structural integrity of natural farming land in the face of cyclonic events. The present study's findings validate the outcomes and discoveries of previous studies, which have consistently demonstrated that various agroecological methods, such as enhancing biodiversity, employing bio-stimulants, and implementing year-round soil coverage, effectively enhance resilience to climate change [45].

Natural farming principles such as 365 Days Green Cover and increased crop diversity, play a vital role in combating climate change impacts. The literature acknowledges that cover crops have been found to have positive impacts on many soil physical and hydraulic parameters, including but not limited to bulk density, total porosity, microporosity, water infiltration, water holding capacity, and hydraulic conductivity [46] [47]. This study has provided preliminary information regarding the comparative resilience of natural farming and chemical farming in minimising the negative impacts of climate change. The data was collected in the aftermath of a limited number of incidents. It is important to further conduct long-term experiments that simulate artificial adverse climatic settings will be crucial for assessing the effects of each principle of natural farming and understanding their cause-and-effect relationships.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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