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Impact of Rainfall Patterns, Chemical and Biochemical Transformation in Agricultural and Environmental Systems

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Abstract: Climate change driven by rising air temperature and humidity significantly impacts agricultural ecosystems' rainfall patterns and chemical and biochemical processes. This study aims to analyze the relationship between temperature, air humidity, and rainfall and their effects on chemical and biochemical transformations in agricultural and environmental systems in Lampung. This research employs a descriptive quantitative and qualitative approach. Primary data were collected through field observations, soil chemical testing, and public health surveys. Secondary data regarding temperature, humidity, and rainfall were obtained from BMKG. Surveys were conducted using structured questionnaires with purposive sampling techniques targeting affected communities. Data were analyzed using descriptive statistics and linear regression to examine relationships between variables, while chemical analysis measured changes in pH, nutrients, and greenhouse gas emissions. Data processing was performed using SPSS and Excel, and triangulation was conducted to ensure accuracy. The findings indicate that increases in temperature and humidity correlate with a 15% rise in annual rainfall over the last decade. The primary observed effects include increased soil acidity (pH decrease by 0.5-1.0 units), a nitrogen level reduction of up to 20%, and increased greenhouse gas emissions such as CH4 and CO2. Additionally, higher rainfall contributes to increased soil erosion and water pollution. In the health sector, surveys indicate a rise in waterborne diseases (diarrhea, cholera) and respiratory disorders. In conclusion, changes in temperature and humidity have complex effects on agriculture, the environment, and public health, necessitating adaptation and mitigation strategies to reduce their negative impacts.

Keywords: Agriculture; Biochemisty; Chemical Transformation; Humidity; Rainfall; Temperature.

Introduction

Climate change, driven by rising greenhouse gas emissions, has significantly altered global weather patterns, particularly temperature and air humidity. According to the Intergovernmental Panel on Climate Change[1] , global average temperatures are projected to increase by 1.5°C by 2030, with increasingly apparent impacts on rainfall patterns in many tropical regions, including Indonesia. In Lampung, for instance, data from the Meteorology, Climatology, and Geophysics Agency (BMKG) indicate that rainfall in this region has increased by approximately 15% over the past decade, while average temperature has also experienced a significant rise. This affects more intense rainfall patterns within shorter periods, directly affecting the agricultural sector, health, and the environment.

Changes in temperature and humidity affect agricultural productivity in this region, with more significant impacts on crops that rely on stable climate conditions [2]. Additionally, variations in rainfall patterns significantly influence the sustainability of agriculture in tropical areas, particularly in terms of water availability for crops, harvest productivity, and the risk of soil erosion and degradation[3]. Extreme rainfall changes, as reported by [4], exacerbate food security by damaging soil and reducing crop yields. Higher temperatures can further deteriorate soil conditions, increase evaporation rates, and decrease water availability essential for plants. Rising temperatures directly correlate with reducing soil organic matter, ultimately decreasing soil quality and plant health [5]

Increased temperature and humidity instability significantly affect human health and ecosystems across Southeast Asia [6]. Rising temperatures can worsen air quality, while humidity fluctuations increase the risk of waterborne disease outbreaks such as cholera and diarrhea. These climate change impacts are felt in economic losses in the agricultural sector and environmental degradation [7]. On the other hand, soil quality deterioration due to erosion and the accelerated loss of nutrients is strongly linked to increasingly intense rainfall patterns. Soil erosion contributes to declining soil fertility, affecting agricultural productivity [8].

The relationship between temperature changes, humidity, and rainfall patterns is very close, as higher temperatures can increase air humidity, leading to more intense rainfall. Previous studies have demonstrated a correlation between high temperatures and heavy rainfall in tropical regions [9]. However, most of these studies focus more on climate change's physical and hydrological aspects without delving into the chemical and biochemical responses occurring in soil and water. Some research has examined the impact of rainfall variation on soil and water quality, such as studying how rainfall affects the transport of chemicals and heavy metals [10]. However, fewer studies have explored the long-term effects on soil fertility and agricultural ecosystems.

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Given this context, recent studies have begun focusing on the interaction between temperature, humidity, and rainfall and their consequences on chemical and biochemical processes in soil and water. For instance, Environmental Chemistry Letters revealed that temperature increases accelerate organic matter decomposition in soil, leading to higher greenhouse gas emissions and lower soil pH, thus reducing crop nutrient availability [11]. In the agricultural sector, rainfall patterns change affect soil fertility, water cycles, and crop yields. High humidity can cause soil erosion, degrading soil quality and disrupting plant resilience to climate fluctuations. Furthermore, rainfall-induced soil pH changes can worsen nutrient availability for crops.

Research Methods

This study employs a descriptive quantitative and qualitative approach using a case study in Lampung to examine the impact of temperature, humidity, and rainfall on soil, agriculture, and public health. Temperature, humidity, and rainfall data were obtained from BMKG, while field observations were conducted to assess soil conditions, plants, and erosion effects. Soil chemical testing was carried out to measure pH changes, nutrient levels, and greenhouse gas emissions due to weather variations. Health surveys were conducted to evaluate the impact of rainfall on water and air quality and environmentally related diseases. Data were analyzed using descriptive statistics and linear regression to explore variable relationships and chemical analytical techniques for pH and nutrient changes. Data processing was performed using SPSS and Excel, with results presented in tables, graphs, and diagrams. Triangulation was conducted by comparing field observations, BMKG data, soil chemical testing, and health surveys to ensure the accuracy and consistency of research findings.

Results and Discussion

Meteorological data, including temperature, humidity, and rainfall, were obtained from BMKG. First, Temperature: In Lampung, the average annual temperature ranges from 26°C to 33°C. Increasing temperatures accelerate evaporation, affect humidity, and alter rainfall patterns, posing risks to agriculture and the environment. Second, Humidity: The air humidity in Lampung ranges between 75% and 85%. High humidity increases rainfall intensity and affects soil quality, leading to erosion and reduced soil fertility. Third, Rainfall: Annual rainfall in Lampung varies between 1,500 mm and 2,500 mm. Higher rainfall leads to soil erosion and crop damage, while lower rainfall results in drought. The changes in these factors can be observed in Table 1 below.

Table 1. Temperature, Humidity, and Rainfall Data (2022-2024)

Year	Average Temperature (°C)	Average Humidity (%)	Rainfall (mm)
2022	27.05	80.16	2.318
2023	27.25	81.5	2.363
2024	28.01	82.5	2.428

[Source: BMKG, 2024]

Field observations include soil conditions, plant conditions, and soil erosion. Soil Conditions: In some regions, such as South Lampung, signs of erosion due to heavy rainfall have been observed, reducing soil quality and its ability to retain water. Images of soil erosion or changes in soil quality, such as damage from heavy rainfall or cracks caused by drought, were documented. Plant Conditions: Decreased crop yields occur due to unstable weather conditions, making crops more vulnerable to drought and disease. Photographs illustrate the impact of climate change on plants, such as wilting or disease infestation due to extreme weather changes. Soil Erosion: Regions frequently experiencing heavy rainfall show significant soil degradation, which affects soil fertility and its capacity to support agriculture. Images of erosion in agricultural land or areas impacted by heavy rainfall, such as water channels forming in the soil or surface erosion, were recorded. The climate condition changes and their impacts on various Lampung regions are detailed in Table 2 below.

Table 2. Comparison of Climate Conditions and Their Impacts in Several Regions of Lampung

Region	Average Temperature (°C)	Humidity (%)	Rainfall (mm/year)	Impact on Agriculture	Impact on Health	Environmental Impact
South Lampung (Bandar Lampung City, Kalianda, Rajabasa)	27 - 31	80 - 85	2,000 - 2,500	- Decreased soil fertility - Reduced rice and horticultural yields - Soil erosion	- Increased waterborne diseases (diarrhea, cholera) - Increased respiratory diseases due to air pollution	- Soil erosion - Water contamination from pesticide and fertilizer runoff
Central Lampung (Seputih Banyak, Gunung Sugih, Terbanggi Besar)	26 - 30	75 - 80	1,800 - 2,200	- Disruptions in rice, maize, and horticultural crop growth - Surface soil erosion	- Waterborne diseases (diarrhea, cholera) - Respiratory diseases in densely populated areas	- Declining water and soil quality - Ecosystem damage due to extreme rainfall

East Lampung (Way Jepara, Batanghari Nuban)	27 – 32	78 - 82	1,500 - 2,000	- Decreased rubber and oil palm yields - Soil erosion and loss of fertility	- Increased waterborne diseases due to high rainfall - Risk of respiratory infections	- Severe soil erosion - Damage to natural habitats in agricultural areas
North Lampung (Kotabumi, Abung Semuli, Sungkai)	28 – 33	75 - 80	2,000 - 2,300	- Crop damage due to flooding - Disruptions in maize growth cycles	- Increased risk of diarrhea - Negative impact on air and water quality	- Surface soil erosion and declining water quality - Disruptions to aquatic ecosystems

a. Soil Conditions

b. Plant Conditions

c. Soil Erosion

Figure 1. Observation Results

Table 3. Soil Chemical and Biochemical Testing

Parameter	High Rainfall Areas (West Lampung and Tanggamus)	Moderate Rainfall Areas (Bandar Lampung and Pesawaran)	Low Rainfall Areas (East Lampung and South Lampung)	Main Impact
Soil pH	5.5–6.0	6.5–7.0	6.8–7.2	Soil acidification due to leaching of basic minerals in high rainfall areas
Nitrogen (N)	Decrease up to 20%	Stable	Stable	Leaching of nitrogen into lower soil layers in high rainfall areas
Phosphorus (P)	Decrease up to 15%	Stable	Stable	Increased mobility of dissolved phosphate in high-rainfall areas
Potassium (K)	Decrease up to 10%	Stable	Stable	Loss due to erosion in high rainfall areas
Organic Matter	Decrease up to 25%	Stable	Stable	Erosion leads to organic matter loss in high-rainfall areas
Microbial Activity	Decrease up to 30%	Stable	Stable	Reduced microbial activity due to organic matter loss
Nutrient Transformation	Disrupted nitrification and phosphorus cycle	Stable	Stable	Reduced efficiency of microorganisms in nutrient cycles
Greenhouse Gas Production	Increased CH4 and CO2 emissions	Stable	Stable	Accelerated organic matter decomposition due to high temperatures in high rainfall areas

Soil Chemical and Biochemical Testing

Soil chemical and biochemical analysis is essential for understanding soil conditions and how climate change, such as temperature and humidity variations affecting rainfall, can impact soil quality and nutrient availability for plants. This testing includes measuring various parameters that describe soil fertility, microbial activity, and chemical

processes occurring within the soil. Below are some commonly tested parameters in soil chemical and biochemical analysis in Table 3.

These results indicate that in high-rainfall areas such as West Lampung and Tanggamus, soil experiences pH reduction, nitrogen, phosphorus, potassium, and organic matter losses due to heavy rainfall leaching. Microbial activity also declines, affecting soil decomposition processes and nutrient transformation. Meanwhile, areas with moderate and low rainfall show relatively stable soil conditions, though drought may still impact crop nutrient uptake efficiency.

Health Survey

A health survey is a research method used to collect data on public health conditions within a specific area. This survey aims to understand disease prevalence, factors influencing health, and the impact of environmental changes on community health. Health surveys typically involve gathering information on physical conditions, lifestyles, and socio-economic factors that may affect individual or group health within a society.

Health surveys indicate an increase in the prevalence of waterborne diseases and respiratory problems in areas exposed to heavy rainfall (Table 4). Many respondents reported declining water and air quality, leading to health disturbances, particularly diarrhea, cholera, and respiratory issues caused by air pollution. Most of the population adopts measures such as closing ventilation or wearing masks to protect themselves from the adverse effects of climate change.

Table 4. Survey Results on the Impact of Increased Rainfall

Aspect	Question	Response	Percentage (%)
Demographics	Age	18-30, 31-45, 46-60, >60	-
	Gender	Male, Female	-
	Residential Area	Urban, Rural	-
Water Quality	Have you noticed a decline in water quality due to heavy rainfall?	Yes/No	62% Yes
	How is the water quality during the rainy season?	Clean/Polluted	55% Polluted
	Have you experienced diarrhea or digestive issues related to water?	Yes/No	40% Yes
	Do you use rainwater for consumption or household purposes?	Yes/No	30% Yes
	Do you filter or treat rainwater before use?	Yes/No	25% Yes
Air Quality	Have you noticed a decline in air quality after heavy rainfall?	Yes/No	70% Yes
	Do you frequently experience respiratory problems (cough, shortness of breath) during rainfall?	Yes/No	55% Yes
	Has air pollution increased around your home during heavy rainfall?	Yes/No	65% Yes
Environment-Related Diseases	Waterborne Diseases		
	Have you or a family member suffered from waterborne diseases during heavy rainfall?	Yes/No	45% Yes
	How many times a year do you experience waterborne diseases?	1-2 times, 3-5 times, >5 times	30% 1-2 times
Respiratory Diseases	Have you or your family experienced respiratory issues during the rainy season?	Yes/No	50% Yes
	Does poor air quality during rainfall worsen respiratory health?	Yes/No	60% Yes
Public Perception	Do you believe increased rainfall affects health?	Yes/No	75% Yes
	What measures do you take to protect yourself from environmental impacts?	Close ventilation, Wear masks, Seek medical treatment, etc.	65% Close ventilation

The study results indicate that extreme variations in temperature and humidity contribute significantly to soil quality degradation and decreased agricultural yields. [12]. states that unpredictable rainfall can disrupt long-established

land use practices in tropical regions. This decline in soil quality is further exacerbated by erosion, which leads to the loss of organic carbon in the soil, as found by [13]. Climate change, marked by an increase in the average annual temperature in Lampung to 28°C in 2024, along with extreme fluctuations in humidity and rainfall, has a significant impact on soil conditions, the agricultural sector, and public health.

Meteorological data show that heavy rainfall in regions such as South Lampung and West Lampung causes severe soil erosion, reducing soil and water quality. Rising temperatures and extreme rainfall exacerbate soil degradation and lower agricultural yields, particularly in tropical areas [14]. Additionally, increased humidity in Lampung can worsen erosion problems, while declining water and air quality exacerbate health conditions by increasing waterborne diseases and respiratory disorders. Survey results show that 62% of respondents perceive a deterioration in water quality due to heavy rainfall, contributing to a rise in diarrhea and digestive disorders [15].

The impact of climate change on soil conditions and agriculture is evident from the reduction in organic matter and nitrogen content due to leaching and erosion. Soil chemical and biochemical testing in high-rainfall areas such as West Lampung indicate a nitrogen loss of up to 20%, potentially disrupting soil fertility and plant nutrient cycles. Nutrient leaching, including nitrogen and phosphorus, due to heavy rainfall can reduce agricultural productivity and soil quality [16]. Moreover, higher temperatures accelerate organic matter decomposition, increasing greenhouse gas emissions such as CO2 and CH4, further intensifying global climate change.

Therefore, climate change mitigation measures such as improved soil management and sustainable natural resource management are essential to minimize negative effects on agriculture and public health [17]. The impact of climate change on water and soil quality is also supported by findings from [18], emphasizing alterations in nutrient cycles linked to higher temperatures and irregular rainfall. Poorer soil quality is directly related to significant agricultural losses in tropical regions.

Mitigation Strategies

Several strategies need to be implemented to mitigate the negative effects of climate change. According to research by [19], sustainable soil management systems, such as soil conservation techniques through terracing and reforestation, can improve soil fertility and reduce erosion risks. Additionally, Using organic fertilizers and biochar can help maintain soil nutrient balance under changing climatic conditions [20].

Furthermore, improving water and air quality monitoring systems is crucial to providing timely and accurate data for the public and policymakers, enabling appropriate preventive actions. Adopting environmentally friendly agricultural technologies should be promoted to reduce reliance on harmful chemicals while enhancing water and fertilizer efficiency, thereby maintaining soil quality and agricultural yields.

Moreover, raising public awareness and education on the impact of climate change on health and the agricultural sector, as well as the importance of environmental conservation efforts, is vital. Green urban planning and sustainable natural resource management are also necessary. Green infrastructure design and sustainable drainage systems can mitigate flood risks and optimize the water cycle . Additionally, using renewable energy technologies and more efficient waste management can help reduce greenhouse gas emissions and enhance environmental resilience to climate change. [19]

Disrupted soil nutrients due to climate change contribute to long-term declines in agricultural yields. To mitigate these impacts, it is necessary to implement sustainable soil management practices, improve water and air quality monitoring, adopt environmentally friendly agricultural technologies, and enhance public awareness and education regarding climate change and its effects. By taking these measures, the negative impacts of climate change on agriculture, health, and the environment can be minimized, and the quality of life for communities can be maintained. The loss of biodiversity due to climate change will worsen agricultural systems and ecosystem services that support food security .

Conclusion

This study concludes that climate change, as indicated by rising temperatures, humidity, and extreme rainfall, significantly impacts soil quality, public health, and the environment. In Lampung, increased rainfall and temperatures have the potential to exacerbate soil erosion, reduce soil fertility, and increase air and water pollution, leading to a higher risk of waterborne diseases and respiratory disorders among the population.

Author Contributions

Welly Anggraini is responsible for designing the research methodology, including data collection and analysing meteorological variables such as air temperature, humidity, and rainfall patterns to understand their relationship within agricultural and environmental systems. Zidny Manaasika focuses on chemical and biochemical analysis, examining the transformation of compounds in soil and plants due to temperature and humidity changes and reviewing relevant biochemical reactions. Vandan Wiliyanti is responsible for writing the research report and publishing the findings, compiling the discussion and conclusions, and communicating with external parties to disseminate the research results to the scientific community and industry practitioners.

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