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Mathematical Approach on Climate Risks in Plant and Vegetation Growth

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ABSTRACT

The objective of this paper work is to propose a mathematical approach on how the climate change affect the vegetation growth. It's aimed to identify the risks based on the climate change, the correlation between them with the impact over the growth and the corresponding equation. With the climate change the vegetation growth changed, so it is important to see how it is affected and how it is changing. The model aim is to define the variables that affect the growth with their corresponding factor of influence, the impact level of the variable in the equation and the total influence on the growth.

Keywords: risks, plants growth, climate change.

INTRODUCTION

Climate risks are significantly impacting plant and vegetation growth. The Earth's climate is constantly changing, and variations in temperature, precipitation patterns, and extreme weather events can have profound effects on plants and their ecosystems. In this article we approach the analyze of some of the key climate risks that influence plant and vegetation growth.

Extreme temperatures, where heatwaves and cold snaps can stress plants. High temperatures can lead to heat stress, increased evaporation, and reduced water availability, while extreme cold can damage tissues and disrupt metabolic processes (Petcu et al., 2018).

As analyzed by (Dong, 2017), accompanying this rapid warming are significant increases in summer mean daily maximum temperature, daily minimum temperature, annual hottest day temperature and warmest night temperature, and an increase in frequency of summer days and tropical nights, while the change in the diurnal temperature range (DTR) is small. Their study focuses on understanding causes of the rapid summer warming and associated temperature extreme changes

Drought, by prolonged periods of low precipitation can lead to drought conditions, causing water stress for plants. Drought reduces water availability, making it difficult for plants to absorb essential nutrients and carry out photosynthesis (Petcu et al., 2014). As in (Walter, 2012) water availability and plant community composition alter plant nutrient availability and the accumulation of plant defense compounds therefore having an impact on herbivore performance. Combined effects of drought stress and plant community composition on leaf chemicals and herbivore performance are largely unexplored. The objective of their study was to find out the impact of extreme drought and of plant community composition on plant-herbivore interactions.

Flooding from the excessive rainfall can be detrimental to many plant species. Floodwaters can deprive plants of oxygen, disrupt root systems, and promote the growth of pathogens (Pujari and Wayal, 2023) stated that urban waterlogging is a common issue in many cities, particularly in low-lying areas, especially during heavy rainfall events.

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Waterlogging refers to the accumulation of water in low-lying areas, which can result in flooding, traffic disruptions, property damage, and health hazards.

Changes in precipitation patterns with the altered precipitation patterns, such as more intense rainstorms or longer dry periods, can affect the timing of plant growth and flowering. This can lead to mismatches with pollinators or disrupt critical life cycles (Hansen, 2023) analyzed that being strongly influenced by internal climate variability, the atmospheric circulation response to greenhouse gas forcing in the future climate is uncertain. Their study addresses atmospheric circulation through representative circulation types (CTs) and investigates the CTs' changes with respect to frequency and effect on surface temperature and precipitation over a pan-Scandinavian domain.

Increased atmospheric CO_2, by rising atmospheric carbon dioxide (CO_2) concentrations can enhance photosynthesis in certain plants, leading to increased growth rates initially. However, this effect may be limited by other factors like nutrient availability or water stress. As (Raihan, 2023) the global climate change caused by Greenhouse Gases (GHGs), particularly carbon dioxide (CO_2) emissions, poses incomparable threats to the environment, development and sustainability. Vietnam is experiencing continuous economic growth and agricultural advancement, which causes higher energy consumption and CO_2 emissions.

Ocean acidification, based on coastal vegetation like mangroves and seagrasses, ocean acidification resulting from increased CO_2 absorption by the oceans can negatively impact growth and survival. Based on (Petersen, 2023) study, the sea level rise driven by global warming is threatening low-lying and reclaimed agricultural areas near coasts. The most marginalized of these with low crop yield can be converted into new valuable wetland ecosystems with high CO_2 mitigation capacity by removing drainage systems or performing managed realignment. This study assessed CO_2 and CH_4 dynamics before and after forming two adjacent wetlands by flooding reclaimed agricultural land.

Pest and Disease Outbreaks. Changes in temperature and precipitation can affect the distribution and abundance of pests and pathogens. Warmer temperatures may promote the spread of certain pests and diseases, putting additional stress on plants. As (Khatri et al., 2023) posted, the current agriculture system has become complex and fragile in recent years. With an increase in population, the demand for food is increasing, but the resources such as arable land and water are limited, and clearing forest land for cultivation and over-extraction of groundwater are changing land-use patterns and depleting groundwater resources, which again are responsible for multiple risks in agriculture and food system. The limited land and water resources with increased global population and its demand for food have mainly stressed small farmers. The rising environment, social and economic risks such as crop disease outbreaks, climate risk causing natural hazards such as floods, famine, drought, exposure to chemicals, technology risks such as genetically modified crops, and biofuels, food demand disparities, demographic and dietary changes, financial risk, conflict and political unrest, biological diversity loss, psychological factors in long-term decision making, and emerging complexity within agriculture system network are the some of the examples of multiple risks faced by small farmers in developing nations.

Extreme Weather Events. Severe storms, hurricanes, and wildfires can cause direct damage to vegetation, leading to loss of biomass and disruption of ecosystems.

Habitat Disruption and Fragmentation. Climate change can force plant species to shift their ranges in response to changing temperature and precipitation patterns. This can result in habitat disruption and fragmentation, affecting plant communities' composition and dynamics.

Phenological Shifts. Climate change can alter the timing of seasonal events like flowering, fruiting, and leaf drop (phenological shifts). This can lead to mismatches with pollinators, seed dispersers, and other species dependent on these patterns.

To mitigate the impacts of climate risks on plant and vegetation growth, it is crucial to develop adaptive strategies such as implementing sustainable land management practices, protecting and restoring ecosystems, conserving genetic diversity, and reducing greenhouse gas emissions (Budău et al., 2023). Additionally, studying and understanding the specific vulnerabilities and resilience mechanisms of different plant species and ecosystems will aid in developing effective conservation and adaptation measures.

A good article about the history of climate change to be mentioned is (Molloy, 2023) where they study the globalizing connections that defined the European Bronze Age in the second millennium BC either ended or abruptly changed in the decades around 1200 BC. The impact of climate change at 3.2 ka on such social changes has been debated for the eastern Mediterranean. This paper extends this enquiry of shifting human-climate relationships during the later Bronze Age into Europe for the first time. There, climate data indicate that significant shifts occurred in hydroclimate and temperatures in various parts of Europe ca. 3.2 ka.

MATERIAL AND METHODS

This research describes a mathematical method for identifying and quantifying risks associated with plant cultivation under changing climate conditions. The method establishes a framework by defining the variables involved, their respective impact, effect models and the correlations between these variables and crop growth. The key element in this method is the calculation of the relative impact of a risk (RIr). The next critical component is determining the damage level of a risk (DLr). The article goes on to identify specific risks associated with plant cultivation in the context of climate change.

The model also considers how these risks interact and influence each other, as climate change rarely acts in isolation. For example, extreme temperatures can lead to heat stress, cold stress, temperature fluctuations, and increased vulnerability to diseases and pests. Drought can result in reduced photosynthesis, stunted growth, wilting, and other negative effects. Flooding can lead to oxygen deprivation, root damage, reduced photosynthesis and more. The model investigates the specific mechanisms by which each risk impacts plant growth, providing a detailed understanding of their effects.

Additionally, changes in precipitation patterns, increased atmospheric carbon dioxide, ocean acidification and pest and disease outbreaks can be assessed in terms of their impact on plant growth. The model incorporates various coefficients to weigh the importance of each risk, reflecting their relative significance in influencing plant growth. These coefficients are based on an average of the calculated relative impact and damage level for each risk.

The final equation for the total influence of all identified risks is derived from the sum of the products of the relative impact, damage level and coefficient for each risk. This equation allows for the quantification of the combined risk factor affecting plant growth due to climate change.

RESULTS AND DISCUSSION

Mathematical approach

In order to be able to define the equation, we must first define the variables involved, their impact and effect model, as well as the correlations between them and plant growth

The following formula is used to calculate the relative impact of a risk RI_r, as presented in Table 1:

$$RI_r = I_r * P_r, \text{ where: (1)}$$

r = risk;
I_r = the impact produced by the risk r;
P_r = probability of applicability of risk r.

Table 1. Impact risk level

Impact/Probability (IP)	Rare (1)	Likely (2)	Periodicals (3)	Regular (4)	Continuous (5)
Insignificant (1)	1	2	3	4	5
Poor (2)	2	4	6	8	10
Medium (3)	3	6	9	12	15
Important (4)	4	8	12	16	20
Catastrophic (5)	5	10	15	20	25

Source: ISO Guide 73:2009 adapted by authors' own research.

The values for the relative impact RI_r are from 1 to 25, where 1 is non-existent and 25 is existing, happening and full damage done.

The damage level of a risk (DL_r) is given by the correlation between the dispersion of the impact surface and the consequences on the growth. There are values by loss categories and corroborated with the relative impact approximates the real mathematical value of the risk identified on the plant growth. A sampling of the injury level is shown in Table 2.

Table 2. Damage level of risks

Losses	Results	DL
Minimal	Minimum chances of affecting the growth	1-10
Low	The growth is affected to a small extent	11-20
Medium	The growth is affected	21-50
High	The growth is greatly affected	51-65
Total	The growth is irreparably affected	66-100

Source: author's adaptation from Stoica (2013).

The identified risks with their corresponding impact level and damage level are:

Risks = ET + D + F + CPP + IACD + OA + PDO, where: (1) based on (2)(5)(6)(7)(8)(9)(10)

ET = Extreme temperatures can have significant impacts on plant growth and development. Plants are sensitive to temperature variations, and extreme heat or cold can disrupt their physiological processes. The effects of extreme temperatures on plants can vary depending on the severity, duration, and timing of the temperature stress (Hatfield and Prueger, 2015; Gurpreet et al., 2021; Rago et al., 2023; Wei et al., 2023).

D = Drought is a prolonged period of inadequate water supply, either due to low precipitation, high evaporation rates, or a combination of both. Drought has a profound impact on plant growth and survival, as water is essential for various physiological processes within plants (Tng et al., 2022; Fard et al., 2023; Ferioun et al., 2023; Zhang et al., 2023).

F = Flooding can have significant and varied effects on plant growth, depending on the duration, depth, and frequency of the flooding event. While some plant species are adapted to survive and even thrive in waterlogged conditions, many others are not well-equipped to handle extended periods of flooding (Hirano et al., 2014; Tewari and Arora, 2016; Wang et al., 2016; Zhu et al., 2023).

CPP = Changes in precipitation patterns can have significant impacts on plant growth and ecosystems. Precipitation is a vital factor that influences the availability of water in the soil, which directly affects plant health, development, and productivity (Ganjurjav et al., 2022; He et al., 2022; Jackson et al., 2023).

IACD = Increased atmospheric carbon dioxide (CO_2) can have both positive and negative effects on plant growth, depending on various factors. CO_2 is a fundamental building block for photosynthesis, the process by which plants convert CO_2, water, and sunlight into energy-rich carbohydrates. As a result, changes in atmospheric CO_2

concentrations can influence plant physiology, development, and productivity (Otieno et al., 2022; Gannon and Cann, 2023; Misra and Jha, 2023; Wang et al., 2023).

OA = Ocean acidification is a process driven by the increased absorption of carbon dioxide (CO_2) by the world's oceans, leading to a decrease in ocean pH. As the oceans absorb more CO_2, they become more acidic. While marine plants, such as phytoplankton and seaweeds, are not directly impacted by ocean acidification, the changes it causes in the marine ecosystem can have indirect effects on their growth. Additionally, seagrasses, which are flowering plants that grow in coastal marine environments, can be directly affected by changes in ocean pH (Osborne et al., 2022; Huang et al., 2023; Liang et al., 2023; Yang et al., 2023).

PDO = Pest and disease outbreaks can have significant detrimental effects on plant growth and overall plant health. These outbreaks are common in both agricultural and natural ecosystems and can result in reduced crop yields, economic losses for farmers, and ecological imbalances (Ratnadass et al., 2021; Contreras-Cornejo et al., 2023; Guégan et al., 2023; Palma et al., 2023).

ET = HS + CS + TS + IVDP, where: (2) based on (3)(4)

HS = Heat Stress, by reduced photosynthesis;

CS = Cold Stress;

TS = Temperature Fluctuations. Rapid shifts between extreme temperatures, such as sudden cold snaps or heatwaves, can be particularly harmful to plants, disrupting their acclimation and adaptive responses. IR_{TS}=15; NL_{TS}=30;

IVDP = Increased vulnerability to diseases and pests. Extreme temperatures weaken plants defense mechanisms, making them more susceptible to infections and pest attacks. IR_{IVDP}=20; NL_{IVDP}=70.

HS = EWL + PT + DEA + PS, where: (3)

EWL = Excessive Water Loss. High temperatures can lead to excessive water loss through transpiration, causing plants to close their stomata. This limits the intake of carbon dioxide, resulting in reduced photosynthesis and overall growth. IR_{EWL}=16; NL_{EWL}=60;

PT = Protein denaturation. Extreme heat can cause proteins within plant cells to denature, leading to cellular damage and dysfunction. IR_{PT}=9; NL_{PT}=25;

DEA = Decreased enzyme activity. High temperatures can reduce the activity of enzymes essential for metabolic processes, negatively impacting growth and development. IR_{DEA}=6; NL_{DEA}=20;

PS = Premature senescence. Heat stress can accelerate the aging process in plants, causing premature leaf senescence and reduced productivity. IR_{PS}=16; NL_{PS}=20.

CS = FD + RMA + IWU + DGD, where: (4)

FD = Frost damage. Frost or freezing temperatures can damage plant cells, causing cell walls to rupture, leading to tissue damage and cell death. IR_{FD}=5; NL_{FD}=80;

RMA = Reduced metabolic activity. Cold temperatures can slow down metabolic processes, including photosynthesis and nutrient uptake, hindering plant growth. IR_{FD}=8; NL_{FD}=30;

IWU = Inhibition of water uptake. Extreme cold can reduce the ability of plant roots to take up water, leading to water stress and potential dehydration. IR_{FD}=8; NL_{FD}=30;

DGD = Delayed growth and development. Cold temperatures can delay the flowering and fruiting stages in many plant species, affecting their reproductive success. IR_{FD}=4; NL_{FD}=15.

Different plant species have different temperature thresholds beyond which their growth is severely affected or even halted altogether. Some plants may be more tolerant of extreme temperatures than others.

D = RP + SG + W + RGI + RFF + IVPD + PLD, where: (5)

RP = Reduced Photosynthesis. During a drought, water availability becomes limited, leading to partial or complete closure of stomata (tiny pores on plant leaves). Stomatal closure is a survival mechanism to reduce water loss through transpiration. However, this also limits the intake of carbon dioxide, which is essential for photosynthesis. As a result, the plant's ability to produce energy through photosynthesis is reduced, leading to slower growth. IR_{RP}=4; NL_{RP}=15;

SG = Stunted Growth. Without sufficient water, plants cannot uptake essential nutrients from the soil. Nutrient uptake often relies on water as a medium to transport minerals to the roots. As a result, the overall growth of the plant is stunted, and it may not reach its full-size potential. IR_{SG}=20; NL_{SG}=45;

W = Wilting. In response to water scarcity, plants may undergo wilting as a means of conserving water. Wilting occurs when cells lose water, causing the plant to lose turgidity and the stems and leaves to droop. Wilting can be reversible if the plant receives water soon enough, but if the drought persists, it can lead to permanent damage and even death. IR_{W}=4; NL_{W}=20;

RGI = Root Growth Inhibition. Drought conditions can reduce root growth in plants. Roots need water to grow and explore the soil for nutrients. With limited water, plants allocate their resources to more essential functions, and root growth may be restricted. This, in turn, reduces the plant's ability to access water and nutrients, creating a vicious cycle of further stress. IR_{RGI}=20; NL_{RGI}=80;

RFF = Reduced Flowering and Fruiting. Drought stress can affect a plant's reproductive capacity. Insufficient water can lead to reduced flower production, and even if flowers are produced, they may not be adequately pollinated due to changes in nectar production or the behavior of pollinators. This results in fewer fruits and seeds being produced. IR_{RFF}=12; NL_{RFF}=35;

IVPD = Increased Vulnerability to Pests and Diseases. Drought-stressed plants are weakened and become more susceptible to pest infestations and diseases. The plant's natural defense mechanisms are compromised, making them more attractive to pests and less able to fend off infections. IR_{IVPD}=20; NL_{IVPD}=70;

PLD = Premature Leaf Drop. In severe drought conditions, plants may shed their leaves as a way of minimizing water loss through transpiration. This process, known as abscission, helps the plant conserve the limited water it has. IR_{PLD}=9; NL_{PLD}=15.

Plants have various strategies to cope with drought stress, such as developing deeper root systems, closing stomata to reduce water loss, and producing compounds that protect against cellular damage caused by drought. However, prolonged or severe drought can surpass the plant's ability to cope, leading to long-term damage and, in extreme cases, death. Drought conditions can also have far-reaching impacts on ecosystems, agriculture, and water resources, affecting both plant and animal populations.

$$F = OD + RD + RP + INU + EP + SD + DS + DFSG, \text{ where: } \quad (6)$$

OD = Oxygen Deprivation. One of the most critical impacts of flooding on plants is oxygen deprivation in the root zone. When the soil becomes waterlogged, air spaces in the soil are filled with water, reducing the availability of oxygen to the plant's roots. Oxygen is essential for root respiration and nutrient uptake, and the lack of oxygen can lead to root death and reduced nutrient absorption. IR_{OD}=12; NL_{OD}=40;

RD = Root Damage. Prolonged flooding can cause root injury and decay due to the lack of oxygen and the presence of harmful microbes in waterlogged soils. Damaged roots can no longer support the plant adequately, leading to reduced water and nutrient uptake. IR_{RD}=12; NL_{RD}=35;

RP = Reduced Photosynthesis. Flooding often results in partial or complete submergence of plant leaves, limiting their exposure to light. Since photosynthesis is crucial for producing energy and building plant tissues, reduced light availability can significantly hinder plant growth. IR_{RP}=12; NL_{RP}=30;

INU = Imbalanced Nutrient Uptake. Flooding can alter the availability of nutrients in the soil. Some nutrients may become unavailable due to the waterlogged conditions, while others, like iron and manganese, may become more abundant but toxic to plants in excess. This can lead to imbalances in nutrient uptake and affect plant health. IR_{INU}=12; NL_{INU}=45;

EP = Ethylene Production. Waterlogged soils promote the production of ethylene, a plant hormone. High levels of ethylene can lead to leaf shedding, premature fruit drop, and other adverse effects on plant growth and development. IR_{EP}=12; NL_{EP}=25;

SD = Susceptibility to Diseases. Flooding weakens plant defense mechanisms, making them more vulnerable to various diseases, particularly root rot and fungal infections.

GS = Growth Stunting. Flooded plants often experience stunted growth due to the multiple stress factors they encounter, including oxygen deprivation, nutrient imbalances, and reduced photosynthesis. IR_{SD}=12; NL_{SD}=65;

DFSG = Delayed Flowering and Seed Germination. Flooding can delay flowering and seed germination in many plant species. The excess moisture interferes with the hormonal and physiological processes that regulate these critical stages of plant reproduction. IR_{DFSG}=12; NL_{DFSG}=55.

It is important to note that some plant species have developed adaptations to survive in waterlogged conditions, such as the ability to tolerate reduced oxygen levels or the development of specialized root structures like pneumatophores (aerial roots) that can obtain oxygen from the air. However, for most terrestrial plants, extended flooding is a stressor that can lead to reduced growth, decreased productivity, and even plant mortality. Flooding can also disrupt ecosystems, affect biodiversity, and impact agricultural productivity in flood-prone areas.

$$CPP = DGG + FR + NA + IE + SPC + IAP + IS + WDE, \text{ where: } (7)$$

DGG = Delayed Germination and Growth. Changes in precipitation patterns can influence the timing and rate of seed germination. Insufficient rainfall can delay or inhibit germination, resulting in a delayed start to plant growth. IR_{DGG}=3; NL_{DGG}=25;

FR = Flowering and Reproduction. Changes in precipitation can also impact the timing and intensity of flowering and reproduction in plants. Insufficient or excessive rainfall can disrupt flowering patterns, leading to reduced seed production and potential impacts on plant populations and biodiversity. IR_{FR}=4; NL_{FR}=35;

NA = Nutrient Availability. Precipitation patterns affect nutrient availability in the soil. Heavy rainfall can leach essential nutrients from the soil, making them less accessible to plants. Conversely, reduced rainfall can concentrate nutrients in the soil, potentially leading to nutrient imbalances and affecting plant growth. IR_{NA}=12; NL_{NA}=20;

IE = Increased Erosion. Intense rainfall events can cause soil erosion, washing away topsoil and valuable nutrients. Erosion can weaken plant health and productivity, especially in agricultural settings. IR_{IE}=5; NL_{IE}=40;

SPC = Shift in Plant Communities. Changes in precipitation patterns can lead to shifts in plant communities and ecosystems. Species that are well-adapted to the new precipitation regime may thrive, while others that are less tolerant may decline or face extinction. IR_{SPC}=12; NL_{SPC}=60;

IAP = Impact on Agricultural Productivity. Changes in precipitation patterns can have significant implications for agriculture. Crops may experience water stress or waterlogging, leading to reduced yields and potential crop failures. IR_{IAP}=9; NL_{IAP}=80;

IS = Invasive Species. Altered precipitation patterns can create new opportunities for invasive plant species to thrive, as they may be better adapted to the changing conditions compared to native species. IR_{IS}=6; NL_{IS}=75;

WDE = Water-dependent Ecosystems. Changes in precipitation patterns can impact water-dependent ecosystems such as wetlands, rivers, and lakes. These ecosystems provide critical habitats for numerous plant species, and alterations in water availability can disrupt their delicate balance. IR_{WDE}=4; NL_{WDE}=55.

Adaptation to changing precipitation patterns is essential for both natural ecosystems and agricultural systems. Proper water management practices, water-efficient irrigation techniques, and the cultivation of drought-tolerant crop varieties are some of the strategies that can help mitigate the impacts of changing precipitation patterns on plant growth and agriculture.

$$IACD = EP + WUE + RSO + APA + NAQ + CPC + PC + IOEF, \text{ where: } (8)$$

EP = Enhanced Photosynthesis. Higher CO_2 levels generally stimulate photosynthesis in most plants, as it increases the availability of the primary substrate (CO_2) for the process. This stimulation can lead to increased plant growth and biomass production, benefiting both natural ecosystems and agricultural crops. IR_{EP}=15; NL_{EP}=75;

WUA = Water Use Efficiency. With higher atmospheric CO_2 concentrations, plants may experience reduced transpiration rates, which is the process by which they lose water through their leaves. As a consequence, plants can improve their water use efficiency, conserving water during periods of water stress or drought. IR_{WUA}=8; NL_{WUA}=25;

RSO = Reduced Stomatal Opening. Elevated CO_2 levels often result in reduced stomatal opening (small pores on the leaf surface). This can lead to a decrease in water loss through transpiration, helping plants conserve water and adapt to arid conditions. IR_{RSO}=4; NL_{RSO}=45;

APA = Altered Plant Allocation. Some studies have shown that increased CO_2 can influence the allocation of resources within a plant, leading to changes in root-to-shoot ratios and the distribution of nutrients. This may result in increased above-ground growth and potentially affect plant competitive interactions. IR_{APA}=4; NL_{APA}=40;

NAQ = Nutrient Availability and Quality. The effects of elevated CO_2 on nutrient availability and quality can be complex and depend on various factors, including soil nutrient status and plant species. In some cases, increased CO_2 can lead to altered nutrient uptake and nutrient dilution in plant tissues, affecting plant nutrition and overall quality. IR_{NAQ}=6; NL_{NAQ}=30;

CPC = Changes in Plant Chemistry. Elevated CO_2 levels can influence the chemical composition of plants, affecting their nutritional value and interactions with herbivores and other organisms. IR_{CPC}=9; NL_{CPC}=25;

PC = Phenological Changes. Higher CO_2 levels may alter the timing of key plant developmental stages, such as flowering and fruiting, leading to shifts in plant phenology. IR_{PC}=3; NL_{PC}=15;

IOEF = Interaction with Other Environmental Factors. The effects of increased CO_2 on plant growth can be influenced by other environmental factors, such as temperature, humidity, and nutrient availability. IR_{IOEF}=12; NL_{IOEF}=65.

$$OA = ICO + DMFC + IS + CMP + AME,$$
where: (9)

ICO = Impact on Calcifying Organisms. Many marine organisms, such as corals, shell-forming mollusks (e.g., clams, oysters), and some species of plankton, rely on calcium carbonate to build their skeletons or shells. Ocean acidification reduces the availability of carbonate ions, making it more challenging for these organisms to form and maintain their calcium carbonate structures. This can indirectly affect marine plants, as many of them rely on these calcifying organisms for habitat and food. IR_{ICO}=5; NL_{ICO}=15;

DMFC = Disruption of Marine Food Chains. Ocean acidification can alter the abundance and distribution of marine species, including plankton, which form the base of marine food chains. Changes in plankton populations can have cascading effects on the rest of the marine ecosystem, potentially affecting the availability of food resources for higher trophic levels, including marine plants. IR_{DMFC}=12; NL_{DMFC}=35;

IS = Impact on Seagrasses. Seagrasses are important marine plants that provide habitat and food for various marine species. Seagrasses can be directly impacted by ocean acidification because they rely on dissolved carbonates to build their tissues. Reduced carbonate availability due to acidification can hinder seagrass growth and weaken their ability to cope with other environmental stresses. IR_{IS}=8; NL_{IS}=20;

CMP = Changes in Marine Productivity. Ocean acidification can affect the growth and productivity of marine plants indirectly by altering nutrient availability and other environmental conditions. If ocean acidification disrupts the balance of marine ecosystems, it can lead to changes in the availability of nutrients and light for marine plants, potentially affecting their growth rates. IR_{CMP}=4; NL_{CMP}=30;

AME = Altered Marine Ecosystems. Ocean acidification can lead to shifts in marine ecosystems, favoring certain species over others. Changes in the dominant species in marine habitats can alter nutrient cycling, trophic interactions, and overall ecosystem dynamics, affecting the growth and distribution of marine plants. IR_{AME}=6; NL_{AME}=75.

It's important to understand that ocean acidification is a global issue driven by increased CO_2 emissions, primarily from human activities like burning fossil fuels and deforestation. While marine plants themselves may not be directly impacted by acidification, they are an integral part of marine ecosystems that can be affected by the changes it brings. The long-term consequences of ocean acidification on marine ecosystems and the implications for global biodiversity and fisheries are still subjects of active research. Mitigating ocean acidification requires concerted efforts to reduce CO_2 emissions and protect marine habitats and biodiversity.

$$PDO = FD + NI + TP + TS + SWD + RRS + IES + CCM, \text{ where: } (10)$$

FD = Feeding Damage. Pests such as insects and mites can feed on plant tissues, causing physical damage to leaves, stems, roots, and fruits. This feeding damage can reduce the plant's ability to photosynthesize, leading to a decrease in energy production and overall growth. IR_{FD}=6; NL_{FD}=15;

NI = Nutrient Imbalance. Some pests and diseases can disrupt nutrient uptake and assimilation in plants. For example, certain pathogens can interfere with root function, hindering the plant's ability to absorb essential nutrients from the soil. Nutrient imbalances can lead to stunted growth and nutrient deficiencies in affected plants. IR_{NI}=4; NL_{NI}=20;

TP = Transmission of Pathogens. Pests, particularly insects, can act as vectors for plant diseases. They can pick up pathogens from infected plants and transfer them to healthy plants during feeding or through physical contact. This transmission can lead to widespread disease outbreaks, further affecting plant growth in a given area. IR_{TP}=3; NL_{TP}=20;

TS = Toxic Substances: Some pests and diseases produce toxic substances that can directly harm plant cells and tissues. These toxins can disrupt cellular processes, leading to cellular damage and impaired growth. IR_{TS}=4; NL_{TS}=30;

SWD = Stress and Weakened Defense. Pests and diseases can cause stress to plants, resulting in altered physiological and biochemical responses. As a consequence, the plant's defense mechanisms may be weakened, making it more susceptible to other stresses and additional pest or disease attacks. IR_{SWD}=8; NL_{SWD}=45;

RRA = Reduced Reproductive Success. Pests and diseases can affect the reproductive capacity of plants. For example, they may cause flower or fruit drop, reducing the number of seeds or fruits produced, and negatively impacting plant reproduction and regeneration. IR_{RRA}=6; NL_{RRA}=75;

IES = Impact on Ecosystems. In natural ecosystems, pest and disease outbreaks can disrupt ecological balances. For instance, an outbreak of pests that feed on a particular plant species may lead to a decline in that species, affecting other organisms that depend on it for food or habitat. IR_{IES}=2; NL_{IES}=55;

CCM = Chemical Control Measures. To manage pest and disease outbreaks, farmers often resort to chemical pesticides and fungicides. While these control measures can help manage the problem, they can also have unintended consequences, such as harming beneficial insects and pollinators, and potentially contaminating soil and water resources. IR_{CCM}=6; NL_{CCM}=70.

Integrated pest management (IPM) strategies, which combine various control methods such as biological controls, crop rotation, and resistant plant varieties, can be more sustainable and effective in managing pest and disease outbreaks while minimizing their impact on plant growth and the environment. Timely monitoring, early detection, and preventive measures are crucial for mitigating the negative effects of pest and disease outbreaks on plant growth and ensuring agricultural productivity and ecosystem health.

Based on the study of the impact level and damage level of the variables identified in the climate change that affect the plant growth, we can estimate the coefficient of each risk in the equation of the total influence as shown in Table 3.

Risks = 1.3 ET + 0.8 D + 0.7 F + 0.5 CPP + 0.6 IACD + 0.7 PDO + 0.2 OA

Table 3. Coefficient of the identified risks and RI, DL average

Variable	RI average	DL average	Coefficient
ET	15	60	1.3
D	16	50	0.8
F	17	55	0.7
CPP	10	30	0.5
IACD	11	35	0.6
PDO	18	40	0.7
OA	10	40	0.2

The risks model is:

$$Risks = \sum_{r=1}^{n} \left(\frac{RI_r}{100} DL_r\right) q,$$ where:

r = risk identified from 1 to n;

q = coefficient proposed in Table 3.

Based on the analyze we can identify the factors of the climate change that affect the plant growth, parse them true the impact level model and the damage level model to can determine the influence of each of them in the plant growth. We can establish a ladder of influence based on the factors allocated to each risk identified, group them by categories or their share in the total equation.

To address these climate risks and their impacts on plant and vegetation growth, it is crucial to implement adaptation and mitigation strategies. These may include sustainable land management practices, conserving and restoring natural habitats, promoting drought-resistant and heat-tolerant plant varieties, reducing greenhouse gas emissions, and enhancing global efforts to combat climate change. Additionally, scientific research and monitoring of ecosystems are vital for understanding the vulnerabilities of plant species to climate risks and formulating effective conservation and management strategies.

CONCLUSIONS

The proposed model for evaluating the risks in plant cultivation due to climate change is a comprehensive framework that takes into account various factors and their impact on plant growth. The model begins by identifying the different risks associated with climate change, such as extreme temperatures, drought, flooding, changes in precipitation patterns, increased atmospheric carbon dioxide, ocean acidification, and pest and disease outbreaks. The model provides a structured and systematic approach to assessing and mitigating the risks associated with climate change. Further research and application of the model can contribute to more resilient and sustainable agricultural practices.

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