





The Future of Human-Plant Synergy in the Age of Remote Interaction

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ABSTRACT

This research investigates the physiological and psychological impacts of tactile interactions with plants, focusing on the comparison between live plants as display mediums and technologically mediated remote relationships. The study aims to understand how these different modes of interaction affect plant growth and human well-being. It also explores the emotional and psychological effects of physical touch with plants on human well-being, particularly in the context of the increasing prevalence of remote interfaces that lead to disconnection from natural environments. The research further examines how specific physiological and psychological responses experienced by individuals when physically interacting with plants utilized as live display mediums compare to the experiences facilitated by remote interaction technology. The research aims to illuminate the symbiotic relationship between humans and plants, potentially influencing future human-plant interactions.

LAND ACKNOWLEDGEMENT

As an immigrant student, I acknowledge that I am on the traditional territory of many nations including the Mississaugas of the Credit, the Anishnabeg, the Chippewa, the Haudenosaunee and the Wendat peoples which is now home to many diverse First Nations, Inuit and Métis peoples. I also acknowledge that Toronto is covered by Treaty 13 signed with the Mississaugas of the Credit, and the Williams Treaties signed with multiple Mississaugas and Chippewa bands. I understand that their history and culture are integral to the land that I live and study on.

As a newcomer to this land, I commit to listening to and learning from Indigenous people and to building meaningful relationships based on mutual respect and understanding. I understand that I have a responsibility to work towards reconciliation and to contribute to creating a more just and equitable society for all.

I offer my sincere respect and gratitude to the Indigenous people who have lived on this land for thousands of years, and I honor their legacy and ongoing contributions to the city of Toronto.

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As I sit to write this acknowledgment, it's like setting off on an expedition through a verdant jungle, filled with creatures that inspire awe. I'm filled with deep gratitude for all my non-human companions and kin, who've been steadfast pillars of encouragement and fountains of inspiration on this journey.

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To my family members, the roots that ground me and the branches that aid my ascent, your love has been the fertile soil from which my dreams sprout. Each one of you has woven into this tapestry of experiences, and for that, I am forever grateful.

DECLARATION

I hereby declare that I am the sole author of this Major Research Project (MRP). This is a true copy of the MRP, including any required final revisions, as accepted by my examiners.

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DEDICATION

To the brightest star in the sky, Baa and Dadu - thank you for your unconditional love and always supporting me to be a part of this wonderful journey.

To all the plants back at home in India with whom I have learned to live and experienced the most beautiful chapters of my life.

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LEGEND

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- Figure 2: Causal Layered Analysis (Iceberg method) (*UN Global Pulse. (2023, May 10). Causal Layered Analysis - UNGP - Foresight Project. UNGP - Foresight Project. <https://foresight.unglobalpulse.net/blog/tools/causal-layered-analysis/>*)
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INTRODUCTION

The Human-Plant Relationship and Its Scope

The relationship between humans and plants is a complex and multifaceted one. It encompasses both direct tactile interactions, where humans physically touch and interact with plants (Huisman, 2020), and technologically mediated remote relationships, where interactions occur through the use of technology (Chang et al., 2022). These interactions can have profound physiological effects on plant growth (Das, 2023) and psychological impacts on human well-being (McDaniel & Panchanathan, 2019).

The purpose of this project is to investigate these tactile relationships between humans and plants, with a focus on the mutual haptic feedback loop. The research is centered on understanding how tactile touch affects human health and plant growth (Huisman, 2020), how tactile encounters with plants affect humans' emotions and psychology (McDaniel & Panchanathan, 2019), the mechanisms that govern the impact of human touch on plant development (Mescher & De Moraes, 2014), and identifying the specific physiological and psychological responses elicited in humans when they physically interact with plants (Calvo, Sahi, & Trewavas, 2017).

Physiological Effects on Plant Growth

Direct tactile interactions with plants can influence their growth and development. This is due to a phenomenon known as thigmomorphogenesis, where plants respond to mechanical stimuli such as

touch (Huisman, 2020). This response can lead to changes in plant growth patterns, such as increased branching or changes in stem thickness. On the other hand, the impact of technologically mediated remote relationships on plant physiological growth is less clear and may depend on the specific technology used. For example, certain sound frequencies could potentially stimulate plant growth, as suggested by the research of Das (Das, 2023).

Psychological Impacts on Human Well-being

Interacting with plants, whether through direct touch or via technology, can have significant psychological benefits for humans. Direct tactile interaction with plants has been found to reduce psychological stress, promote feelings of comfort, and enhance a sense of calm (McDaniel & Panchanathan, 2019). Similarly, the presence of virtual plants in a virtual reality environment has been shown to improve cognitive performance and psychological well-being. Although the increasing use of remote interfaces may lead to users becoming disconnected from natural ecosystems, it also creates new opportunities for human-plant connection. These interfaces can be engineered to not only preserve, but even amplify the psychological advantages obtained by engaging with plants (Chang, Shen, Maheshwari, Danielescu, & Yao, 2022b).

Human-Plant Affiliations and Interactions

The concept of "Phytograms", proposed by Karel Doing, suggests an image made using the internal

chemistry of plants in conjunction with photographic emulsion (Doing, 2020). This offers a unique way of human-plant interaction and a new perspective on our relationship with plants. Similarly, the design of Human-Plant Interaction, as discussed by Chang et al., presents patterns and opportunities for creating meaningful and engaging experiences (Chang et al., 2022).

LIMITATIONS

While the research is thorough, it contains a number of limitations that need to be taken into account. Technological restrictions can affect the applicability of findings, as the availability and complexity of technology might vary significantly among locations and populations (Chang et al., 2022). The research also fails to adequately consider the subjectivity of psychological effects, as the psychological effects of physical contact with plants on human well-being might differ significantly among individuals (McDaniel & Panchanathan, 2019). This has the potential to impact the outcomes and restrict the applicability of the conclusions.

The research does not include longitudinal data, which is necessary to understand the long-term impacts of physical contacts with live plants and technology facilitated remote relationships on both plant development and human well-being (Das, 2023). Although the research acknowledges the importance of institutional regulations and ethical principles, it fails to address the specific ethical concerns that may occur when implementing its recommendations. This omission could be a serious drawback (Huisman, 2020).

The research does not completely take into account the socio-cultural elements that can have a substantial impact on the feasibility and success of integrating plants into HCI designs. Furthermore, the analysis fails to consider environmental conditions that could impact plant growth and, consequently, the efficacy of plants as display mediums (Das, 2023).

It is important to take into account these limitations when analyzing the results and suggestions of the research. Subsequent investigations should focus on overcoming these constraints in order to achieve a more thorough comprehension of the topic at hand (Chang et al., 2022).

RESEARCH QUESTIONS

How do tactile interactions with live plants as display mediums and technologically mediated remote relationships differ in their physiological effects on plant growth and psychological impacts on human well-being?

What are the emotional and psychological effects of physical touch with plants on human well-being in the context of increasing prevalence of remote interfaces that lead to disconnection from natural environments?

How do specific physiological and psychological responses experienced by individuals when physically interacting with plants utilized as live display mediums compare to the experiences facilitated by remote interaction technology?

RESEARCH ETHICS BOARD DECLARATION

The research completed for this Major Research Paper was conducted with the approval of the OCAD University Research Ethics Board (REB protocol #2024-14)

DESIGN RESEARCH METHODOLOGIES

My secondary research up to this point has helped me frame an understanding of the domain, some of the problems surrounding me, and the way the problems are interwoven with each other. I started building a methodology for my primary research. The following steps detail my methodology, in a sequential manner, starting from defining my objectives to collecting and synthesizing data to inform research outcomes.

I began with a comprehensive literature review to understand the domain and identify the problems. This was followed by Rich Context Mapping to visualize the interconnections between these problems. Next, Causal Layered Analysis (CLA) was employed to delve deeper into the issues and uncover the underlying layers. This was complemented by Horizon Scanning to identify emerging trends and disruptions in the field. A survey was then conducted to gather primary data, which was subsequently analyzed to extract meaningful insights. The survey data was further enriched through another round of Causal Layered Analysis (CLA), providing more context to the data. Finally, the Three Horizons framework was used to envision possible futures and identify pathways for strategic innovation.

This methodology was instrumental in framing an understanding of the domain, identifying and interconnecting problems, and starting the process of building a methodology for primary research. The steps detailed above were followed in a sequential manner, starting from defining objectives to

collecting and synthesizing data to inform research outcomes.

The objective of this section is to delineate the methods employed for doing my primary research. This methodology played a crucial role in developing a comprehensive understanding of the subject matter, as well as finding and establishing connections between various challenges. The following procedures were executed in a sequential manner, commencing with the establishment of objectives and proceeding to the gathering and synthesis of data to inform the conclusions of the research.

Literature Review:

This stage entailed a meticulous examination of the current body of literature in the specific field. The objective of this stage was to gain comprehension of the field and ascertain the issues at hand. It established a strong basis for the subsequent study.

Rich Context Mapping:

The methodology of Rich Context Mapping was employed to visually represent the interrelationships among the concerns discovered in the literature review. It facilitated comprehension of the intricacy and interconnectedness of the matters under consideration (Jones & Van Ael, 2022b).

Causal Layered Analysis:

Causal Layered Analysis (CLA) was utilized to conduct a thorough examination of the issues and reveal the fundamental layers beneath.

This approach facilitated the comprehension of the fundamental factors behind the issues and their interdependencies (Inayatullah, 1998).

Horizon Scanning:

Horizon scanning encompasses the process of recognizing nascent trends and disturbances within the domain. The objective of this stage was to comprehend the forthcoming course of the domain and its potential influence on the highlighted issues (Baghai et al., 1999).

Conducting a Survey:

A survey was carried out to collect primary data. This stage was essential in confirming the findings from the literature review and the subsequent analysis.

Analyzing the survey:

The survey data was evaluated to derive significant findings. This stage facilitated comprehension of the viewpoints held by the stakeholders concerned.

Casual Layered Analysis based on Survey:

A subsequent iteration of Causal Layered Analysis (CLA) was performed using the survey data. This additional information added further context to the data, facilitating the identification of patterns and trends (Inayatullah, 1998).

Three Horizons based on Survey:

The Three Horizons paradigm was applied to envisage potential future scenarios and determine strategic innovation pathways. This step was crucial

in formulating strategic suggestions derived from the research findings (Baghai et al., 1999).

This methodology facilitated my comprehension of the subject, enabled me to recognize and establish connections between research gaps, and established a strong basis for my primary study. The outcomes of each stage are elaborated in the subsequent sections.

Rich Context Mapping

Rich context mapping is a strategic tool used to identify and understand the intricate connections within a system. It serves as a lens to examine long-term societal trends (landscape), current practices upheld by policies and organizations (regime level), and emerging innovations (niche) that have the potential to address these trends (Jones & Van Ael, 2022a).

This tool is instrumental in constructing a comprehensive understanding of the most critical system contexts. It allows for the identification of key elements within a system and their interrelationships, thereby providing a holistic view of the system's functioning (Jones & Van Ael, 2022a).

The choice of this method was driven by its ability to provide a detailed and nuanced understanding of the system and its contexts. It offers a structured approach to navigate through complex systems, making it an invaluable tool in systemic design (Jones & Van Ael, 2022a).

In essence, rich context mapping is a powerful tool that enables designers to navigate through the complexities of a system, understand its dynamics, and identify opportunities for impactful interventions (Jones & Van Ael, 2022a).

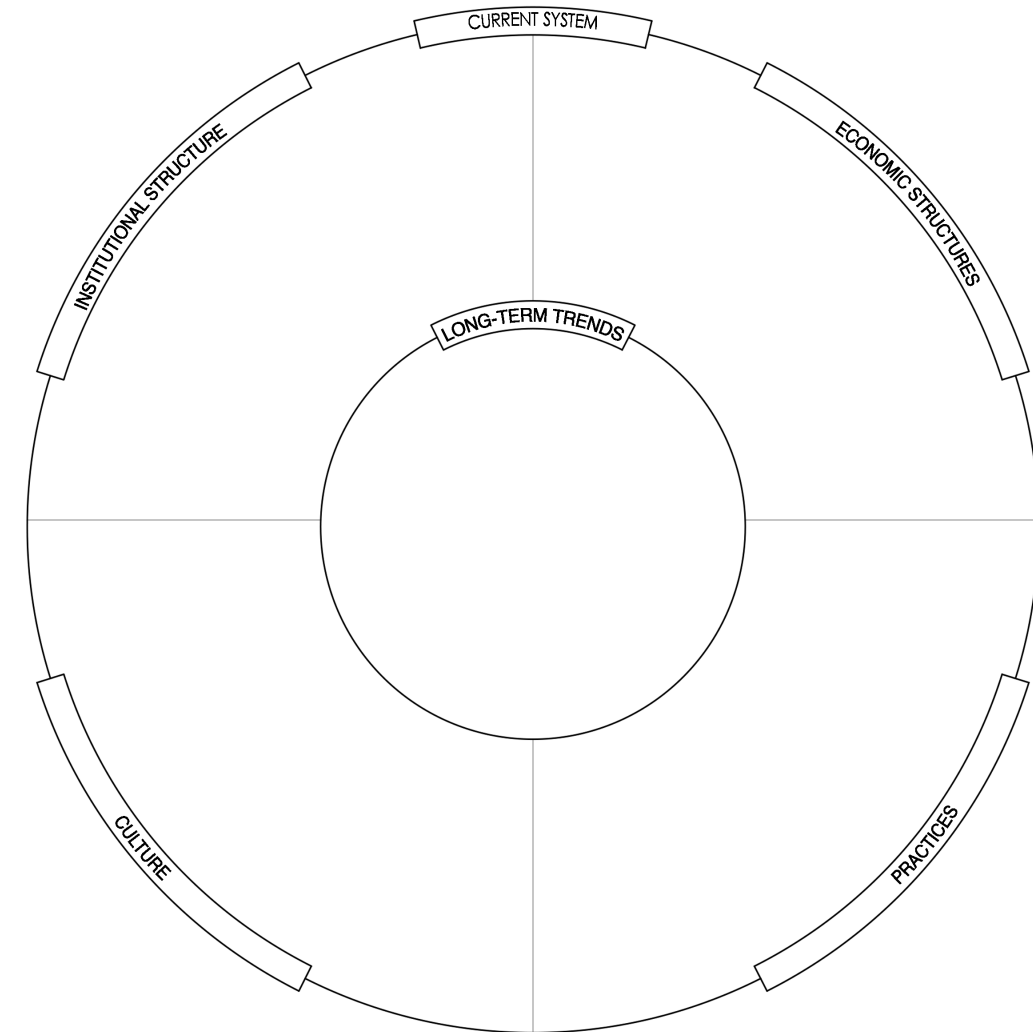


Figure 1: Rich Context Mapping

Casual Layered Analysis

The Causal Layered Analysis (CLA), a methodology developed by Sohail Inayatullah, is composed of four distinct levels: the litany, social causes, worldview, and myth.

The litany is the first level, which represents the observable phenomena and issues that are typically reported in the media. It is the surface level of reality, often quantifiable and easily measurable (Inayatullah, 2004).

The second level, social causes, delves deeper to explore the social, economic, and political factors contributing to the litany. It uncovers the systemic causes behind the observable phenomena (Inayatullah, 2004).

The third level, the worldview, examines the cultural, ideological, and belief systems that underpin the social causes. It explores how different perspectives shape our understanding and interpretation of reality (Inayatullah, 2004).

The final level, the myth, delves into the collective unconscious. It uncovers the deep stories, metaphors, and myths that influence our worldviews (Inayatullah, 2004).

The CLA employs a vertical approach, moving from the litany to the myth and metaphor. This approach aims to uncover insights that one might miss if they were only looking at the 'tip of the iceberg'.

This analysis served to enrich the insights uncovered in the previous layers and provided an emotional experience to the worldview under inquiry (Inayatullah, 2004).

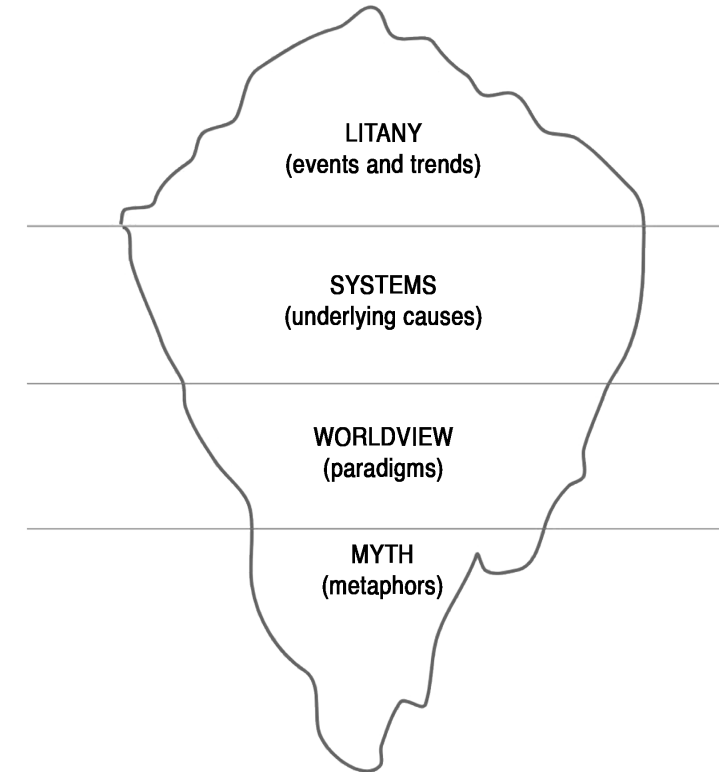


Figure 2: Causal Layered Analysis (Iceberg method)

Horizon Scanning

This methodology is well-known in strategic foresight for its ability to integrate complex systems ideas and map out future strategic pathways. The Three Horizons methodology was used to discover the relationships of change and innovation over the shift of temporal transitions toward preferred future outcomes. It introduces the powerful idea that multiple futures can coexist in any present moment. The three overlapping horizon curves provide a heuristic for determining the strategic fit of actions chosen to promote a desired future vision, versus a continuation of default 'business as usual' or non-desired outcomes. This idea challenges the conventional linear perception of time and progress, suggesting a more fluid and multifaceted understanding of the future (Baghai et al., 1999).

The Three Horizons methodology is visualized through three overlapping horizon curves. Each curve or 'horizon' represents a different temporal and strategic perspective.

The first horizon (H1) represents the current paradigm or 'business as usual.' It is characterized by existing systems and practices that may be resistant to change. However, these are also the systems that are likely to decline over time as they become increasingly unfit for future contexts (Baghai et al., 1999).

The second horizon (H2) is the realm of emerging innovations, disruptions, and transitional elements that challenge the status quo. These are often novel ideas or technologies that have the potential

to reshape the current paradigm but are still in a nascent or unstable state (Baghai et al., 1999).

The third horizon (H3) embodies the long-term vision for the future. It is the desired state or outcome that guides strategic actions and decisions. This horizon is often aspirational, representing the values, principles, and systems that are believed to be desirable for the future (Baghai et al., 1999).

The interplay of these three horizons provides a heuristic for determining the strategic alignment of actions chosen to promote a desired future vision, versus a continuation of default 'business as usual' or non-desired outcomes. By understanding the dynamics and interactions between these horizons, organizations can navigate the complexities of strategic planning and decision-making in an uncertain and changing environment (Baghai et al., 1999).

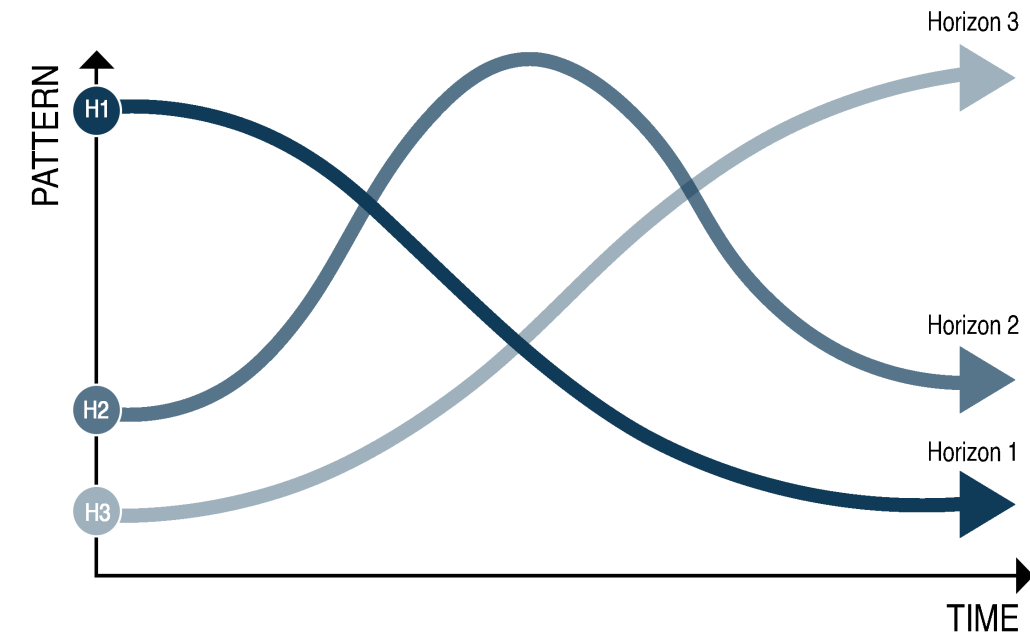


Figure 3: Horizon Scanning

LITERATURE REVIEW

Title: Phytograms: Rebuilding Human–Plant Affiliations by Doing

Summary: The study by Doing (2020) presents a novel method called phytograms, aimed at restoring the connection between humans and plants. Phytograms are graphical representations that illustrate plant responses to various stimuli, thereby enhancing our understanding of plant behavior and fostering a deeper bond between humans and flora. They convert raw data into animated visual representations, allowing for a more comprehensive perception that goes beyond mere observation. Phytograms underscore the dynamic relationship between humans and plants, emphasizing that plants are not static but responsive to environmental stimuli. They encourage tactile engagement, promoting hands-on interaction despite the prevalent role of technology in our interactions with the natural world.

Keywords: Phytograms, Human-Plant Affiliations, Animated Visuals, Plant Reactions, Tactile Engagement, Ecological Consciousness, Design and Education.

Relevance to Research Questions: The research introduces phytograms as a solution to the growing disconnect between humans and the natural environment due to urbanization and technology integration. It addresses the research question of how to restore and enhance human-plant connections in a digital age.

Research Gaps: While the study highlights the potential of phytograms in stimulating creative concepts and educational exhibits, further research could explore the practical implementation and effectiveness of these applications. Additionally, the impact of phytograms on ecological consciousness and environmental stewardship could be empirically measured to substantiate the claims made in the study.

Title: Green Fingers: Plant Thigmo Responses as an Unexplored Area for Haptics Research by Huisman

Summary: This research by Huisman (2020) investigates the physiological effects on plant growth and the psychological impacts on human well-being when interacting with plants through tactile means and technologically mediated remote relationships. It emphasizes the concept of Plant Thigmomorphogenesis, which is the response of plants to mechanical stimulation such as touch, leading to changes in growth patterns, hormone release, and gene expression.

Keywords: Plant Thigmomorphogenesis, Human-Plant Interaction, Remote Interfaces, Physiological Effects, Psychological Effects.

Relevance to Research Questions: In the context of “Green Fingers: Plant Thigmo Responses as an Unexplored Area for Haptics Research” by Huisman (2020), the research questions explore the physiological and psychological impacts of human interaction with plants, both through direct touch and technologically mediated remote relationships. They address the implications for human disconnection from natural environments and the anthropocentric treatment of plant ecosystems. The questions also delve into the specific physiological and psychological responses individuals experience when physically interacting with plants utilized as live display mediums.

These questions are crucial for informing and enhancing human-technology interfaces in a digitized society, a key focus of Huisman’s research. They highlight the need for a balance between technological progress and our inherent desire for natural encounters.

Research Gaps: There are several areas in the intersection of human-plant interaction and technology that require further exploration. Firstly, the physiological effects of different types of human interactions, such as direct touch compared to remote interfaces, on plant growth are not fully comprehended. Secondly, the psychological implications of these interactions on human well-being are yet to be extensively studied. This includes both direct touch and remote interactions with plants. Lastly, the impact of remote interaction technology on the human connection with the natural world is another area that warrants additional investigation. These gaps underscore the need for more research to better understand the intricate relationship between humans, technology, and nature.

Title: Therapeutic Haptics for Mental Health and Wellbeing by McDaniel, T., & Panchanathan, S. (2019).

Summary: This literature review focuses on the intersection of haptic technologies and mental health, specifically their potential therapeutic uses. The study explores the impact of tactile contact with living plants on both plant development and human well-being, the consequences of using plants as display media, the effects of technology-facilitated remote relationships with plants, and the physiological and psychological reactions to live display mediums compared to remote interaction technology.

Keywords: Haptic technologies, mental health, well-being, tactile contact, living plants, display media, remote relationships, physiological reactions, psychological reactions.

Relevance to Research Questions: The research questions focus on the interaction between humans and plants, both physically and remotely via technology. The paper provides valuable insights into these areas, although it does not directly answer the research questions. It discusses the effects of physical touch with plants on emotions and psychology, and compares this with the experiences enabled by remote engagement technology.

Research Gaps: The paper does not directly address the research questions about the impact of employing plants as display media, the consequences of the detachment of humans from natural surroundings, and the anthropocentric handling of plant ecosystems. These could be potential areas for further research.

Title: “Entangled Life: How Fungi Make Our Worlds, Change Our Minds & Shape Our Futures” by Merlin Sheldrake.

Summary: The book explores the profound and interconnected relationship between plants and fungi. It delves into the mysterious world of fungi that significantly impact ecosystems, influence human cognition, and potentially shape our shared future. The study also examines the intricate relationship between human touch and computer interfaces, considering the interconnectedness of life through fungal threads.

Keywords: Fungi, Ecosystems, Human cognition, Physical contact, Computer interfaces, Plant development, Psychological well-being, Technology, Emotional impacts, Environmental consciousness.

Relevance to Research Questions: The book investigates the physiological effects on plant development and psychological impacts on human well-being from both physical contact with plants and remote relationships facilitated by technology.

It examines the consequences of humans becoming disconnected from natural habitats and prioritizing their needs over plant ecosystems.

It explores the effects of technology on human-plant interactions, comparing the impacts of remote connections with traditional physical interactions.

It considers the emotional and psychological effects of physical contact with plants on human welfare, especially in the context of increasing disconnection from natural surroundings due to technology.

Research Gaps: The book identifies a need for longitudinal research to investigate the long-term impacts of physical contacts with plants and remote connections, including the role of fungi.

It calls for research into the principles of designing technology that facilitates interactions between plants and incorporates the role of fungi.

It highlights the need for research on how virtual environments can elicit emotional responses comparable to physical green landscapes, considering fungal biodiversity.

It emphasizes the importance of raising awareness about the crucial role of fungi in maintaining ecosystems and promoting ethical plant care practices.

Title: “The Hidden Life of Trees: What They Feel, How They Communicate—Discoveries from A Secret World” by Peter Wohlleben.

Summary: The book explores the complex existence of trees, their communication, emotions, and physiological processes. It emphasizes the deep ties between humans and the natural environment. The book discusses the benefits of tactile interactions with live plants and the drawbacks of remote relationships facilitated by technology. It highlights the impact of these interactions on human well-being, plant growth, emotions, and psychology.

Keywords: Tactile Interactions, Remote Relationships, Human Well-Being, Plant Growth, Emotions, Psychology, Disconnection from Nature.

Relevance to Research Questions: The book is highly relevant to research questions exploring the relationship between humans and nature, particularly focusing on the effects of tactile and remote interactions with plants on human and plant well-being.

Research Gaps: The book identifies several research gaps, including the need for empirical studies to authenticate the physiological and psychological reactions linked to tactile contact and distant connections. It also calls for research into how cultural variations affect human-plant relationships and the long-term implications of remote interfaces compared to direct contact.

Title: The distinctive capacities of plants: re-thinking difference via invasive species

Summary: This study challenges the traditional Western belief that plants are inferior to animals. It presents a new perspective that recognizes the collective abilities of plants and discusses the implications of these abilities on plant growth and human well-being. The authors argue that direct physical contact with plants has different physiological and psychological effects compared to remote interactions facilitated by technology.

Keywords: Plants, Collective Abilities, Physical Properties, Autonomous Movement, Sensory Perception, Communication, Adaptable Physical Forms, Human-Plant Interactions, Remote Interfaces, Psychological Well-being, Plant Physiological Progress.

Relevance to Research Questions: The study is relevant as it provides a fresh perspective on the abilities of plants and their interactions with humans. It could offer valuable insights into the physiological and psychological impacts of physical contact with plants on human well-being, especially in the context of increasing use of remote interfaces.

Research Gaps: The authors highlight the need for more scholarly research on our interactions with plants. They note that progress in this area is hindered by a deeply ingrained intellectual legacy. This suggests a research gap in understanding the specific physiological and psychological reactions that humans have when physically interacting with plants used as live display mediums, and how these reactions compare to experiences facilitated by remote interaction technologies. The study calls for a reevaluation of concepts such as agency, subjectivity, and the moral implications of causing plant demise, which are often assessed based on human standards.

Title: Role of plant sensory perception in plant-animal interactions by Mescher, M. C., & De Moraes, C. M. (2014) published in *Journal of Experimental Botany*, 66(2), 425–433.

Summary: The paper investigates the complex perceptual capabilities of plants, challenging the traditional view of plants as passive organisms. The authors explore various mechanisms by which plants sense and respond to their environment, such as identifying and capturing animal prey, actively responding to pollinator visits, and recognizing cues related to herbivory. These findings suggest that plants have sophisticated sensory awareness and responses, which could have implications for plant growth and human well-being in terms of touch interactions and technologically facilitated distant connections.

Keywords: Plant sensory perception, plant-animal interactions, sensory stimuli, touch interactions, technologically facilitated distant connections.

Relevance to Research Questions: Although the paper does not directly address the effects of physical interactions with live plants compared to technologically mediated remote relationships on plant growth and human well-being, it provides a foundational understanding of how plants perceive sensory stimuli. This understanding could be a crucial element in these interactions and could guide future research in this field.

Research Gaps: The authors acknowledge that our understanding of the full range of sensory signals involved in plant-animal interactions, as well as the mechanisms by which plants perceive, interpret, and respond to these cues, is still in its early stages. This highlights a significant gap in the existing research. Future studies could aim to fill this gap by investigating the impact of plant sensory perception on plant growth and human well-being, particularly in relation to physical interactions with live plants and the use of technology to create remote connections.

Title: “Are plants sentient?” by Calvo, Sahi, and Trewavas (2017) published in *Plant, Cell & Environment*.

Summary: The paper explores the ongoing debate about plant sentience. The authors argue that while plants exhibit complex responses to their environment, it is unclear whether these responses can be considered as consciousness in the conventional sense applied to animals.

Keywords: Plant sentience, consciousness, environmental responses, physiological processes.

Relevance to Research Questions: The paper’s exploration of plant sentience is directly relevant to your research questions, which focus on the physiological effects on plant growth and the psychological impacts on human well-being from tactile interactions with live plants versus technologically mediated remote relationships.

Research Gaps: The paper highlights the ongoing debate and differing viewpoints within the scientific community about plant sentience. This suggests a need for further research to conclusively determine whether plants possess sentience and to understand the implications of this for human interactions with plants. The paper also raises questions about the psychological and emotional impacts of physical contact with plants on human welfare, suggesting another potential area for further research.

Title: “Potential effects of audible sound signals including music on plants: A new trigger” by Mousumi Das, published in the Environment Conservation Journal in 2023.

Summary: The paper investigates the effects of audible sound signals, including music, on plant growth and physiology. It also explores the psychological effects of these interactions on human welfare.

Keywords: Plant Acoustic Frequency Technology (PAFT), sound waves, medicinal plants, plant life cycle, molecular and cellular alterations, plant defense mechanisms, fruit quality, drought tolerance, ecological interactions.

Relevance to Research Questions: The study is relevant to the research question about the physiological effects of sound on plant growth. It also indirectly addresses the question about the psychological impact of using technology to foster a remote relationship with plants on human mental health.

Research Gaps: The paper identifies several gaps in the current research. The process by which plants first detect and identify sound signals remains unclear. More empirical investigations are needed to develop an appropriate strategy for implementing sound therapy in agricultural production.

The paper also emphasizes the need to understand the impacts of specific frequencies and intensities, as well as the duration of sound exposure, in the context of sound therapy.

RESULTS

Step-1: Rich Context Mapping

Rich Context mapping involves the process of identifying, analyzing, and visualizing the various elements and their interrelationships within a system. In this case, the system pertains to the integration of technological advancements with nature, and the contexts include social, economic, cultural, and institutional aspects. The purpose of this mapping is to gain a holistic understanding of the current scenario and to anticipate future trends. It aids in making informed decisions and strategies that are sustainable and respectful of nature.

The rich context mapping exercise conducted here has provided a comprehensive understanding of the system and its contexts. It has highlighted the importance of balancing technological advancements with sustainability and respect for nature. It underscores the significance of social connectivity, well-being, education, and personal enjoyment in the design process. The exercise has identified long-term trends towards environmentally conscious behaviors, social connectivity, prioritizing mental and physical health, advancements in education, integration of digital and natural worlds, and the importance of personal enjoyment. These trends are shaping the future of interaction design and technology, making Rich Context Mapping an essential tool in understanding and navigating these shifts. It also emphasizes the need for institutional policies and ethical criteria to balance the benefits of remote technology with the necessity of maintaining a genuine connection to nature. This aligns with the research questions on tactile interactions vs remote relationships, emotional

and psychological effects of physical touch, and comparison of physiological and psychological responses.

Long term trends

Sustainability in Interaction Design: The discourse in interaction design has seen a paradigm shift towards environmentally conscious behaviors and practices that underscore long-term sustainability (Chang et al., 2022b). This is exemplified by the development of interfaces that incentivize users to minimize their carbon footprint, such as applications that monitor and regulate energy consumption. However, it is crucial to consider the potential risks and counter-trends, such as the increased energy consumption of digital devices and data centers, which could offset the benefits of these sustainable practices (Kez et al., 2022).

Social Connectivity: The advent of technology has catalyzed the formation of social bonds and cooperative efforts (Chang et al., 2022b). This trend is manifested in the proliferation of social media platforms and collaborative tools, which have revolutionized the way individuals connect and collaborate, transcending geographical boundaries. However, a growing body of research suggests that social media may actually be leading to decreased social connectivity by creating echo chambers that only mimic connectivity. This highlights the importance of examining all possible outcomes when analyzing trends, as this approach allows us to identify potential sites of intervention where we can influence or predict (Terren & Borge, 2021).

Enhancing well-being with Technology: The design landscape is increasingly prioritizing mental and physical health (McDaniel & Panchanathan,

2019). A case in point is the emergence of fitness applications that not only track physical activities but also incorporate features that foster mental well-being, such as guided meditation. However, it is important to consider the potential risks associated with over-reliance on technology for health and well-being, such as privacy concerns and the potential for increased sedentary behavior.

Advancements in education: The pedagogical sphere is witnessing the integration of interactive tools for studying plants (Huisman, 2020). Augmented reality applications, for instance, are being leveraged in botany classes to provide students with an immersive and hands-on learning experience. However, it is important to consider the potential drawbacks of this trend, such as the digital divide and the risk of over-reliance on technology in education (Afzal et al., 2023).

Integration of the digital and natural worlds: There is a growing trend towards creating immersive experiences that foster a connection between users and nature (Doing, 2020). This is evident in the advent of virtual reality nature tours, which enable users to explore natural environments without leaving their homes. However, it is important to consider the potential risks of this trend, such as the risk of substituting real-world experiences virtual ones, and the environmental impact of producing and disposing of VR equipment (Pellegrino et al., 2023).

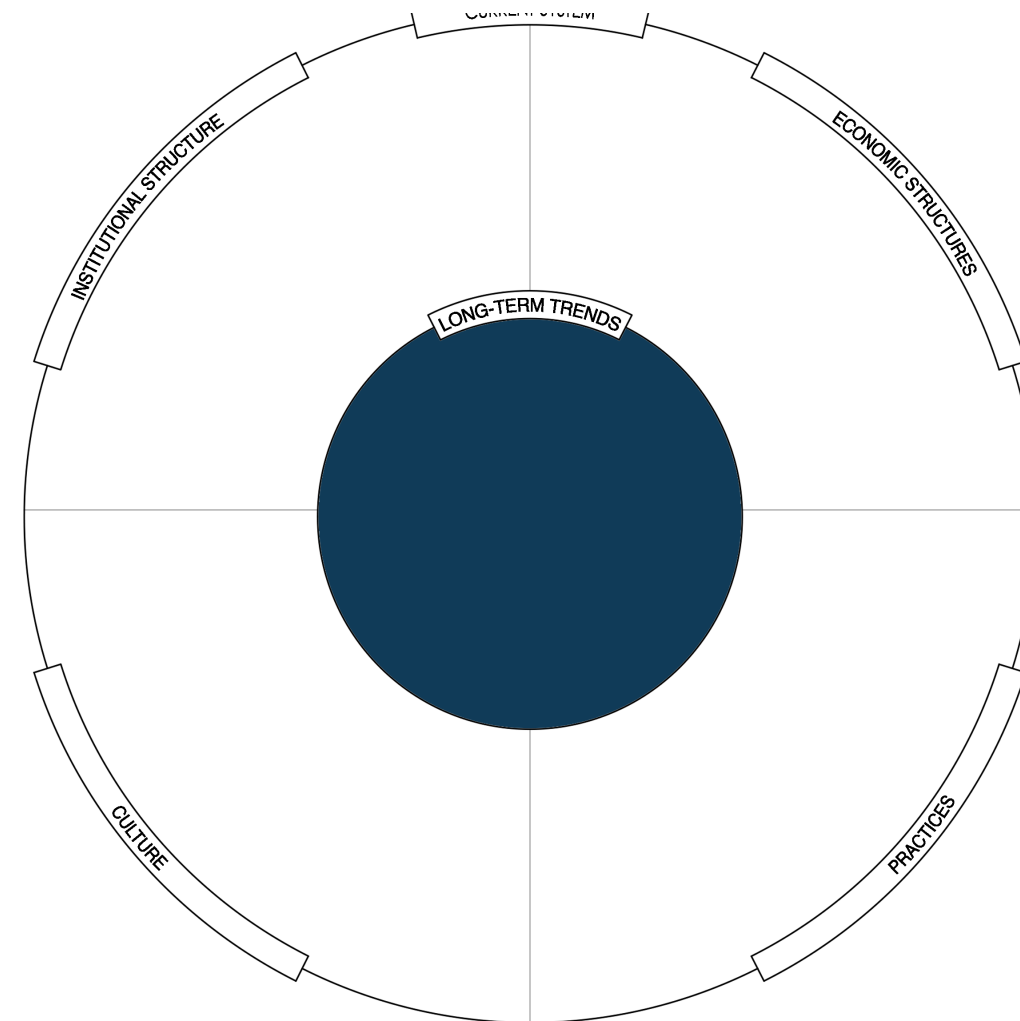


Figure 4: Long term trends (Rich Context Mapping)

The Significance of Personal Enjoyment: The role of pleasure and active involvement in relationships is gaining recognition (Wohlleben, 2016). This is reflected in the use of gamification techniques in

applications to render mundane tasks more enjoyable, thereby enhancing user engagement.

Institutional Quadrant

Policy Development: Institutions should create policies that strike a balance between the advantages of remote technology and the necessity to maintain a genuine connection to nature. For instance, Chang et al. (2022b) discuss how remote technology can improve efficiency and accessibility but also warn about the risk of losing touch with the natural environment. Therefore, policies could include guidelines for technology use that encourage regular interaction with nature.

Ethical Criteria: It's important to create ethical criteria to prevent ecological oversimplification and ensure that remote technologies do not lead to a disconnect from the natural environment. Doing (2020), Huisman (2020), and McDaniel & Panchanathan (2019) all emphasize the need for ethical guidelines in technology use. For example, these could include rules against using technology to replace direct interaction with nature.

In addition, we should implement principles that prevent plants from being objectified, acknowledging them as living beings with intrinsic value in addition to their function as interfaces. Sheldrake (2021) and Wohlleben (2016) both argue for the recognition of plants as more than just resources, suggesting that our ethical guidelines should reflect this perspective.

Awareness and Education: Raising awareness and education about the necessity of sustaining ecosystem complexity, as well as the ethical implications of distant technology use is crucial.

Head et al. (2014), Mescher & De Moraes (2014), Calvo et al. (2017), and Das (2023) all highlight the importance of education in promoting a healthy relationship with nature. This could involve educational programs that teach about the complexity of ecosystems and the potential ethical issues with using technology to interact with nature.

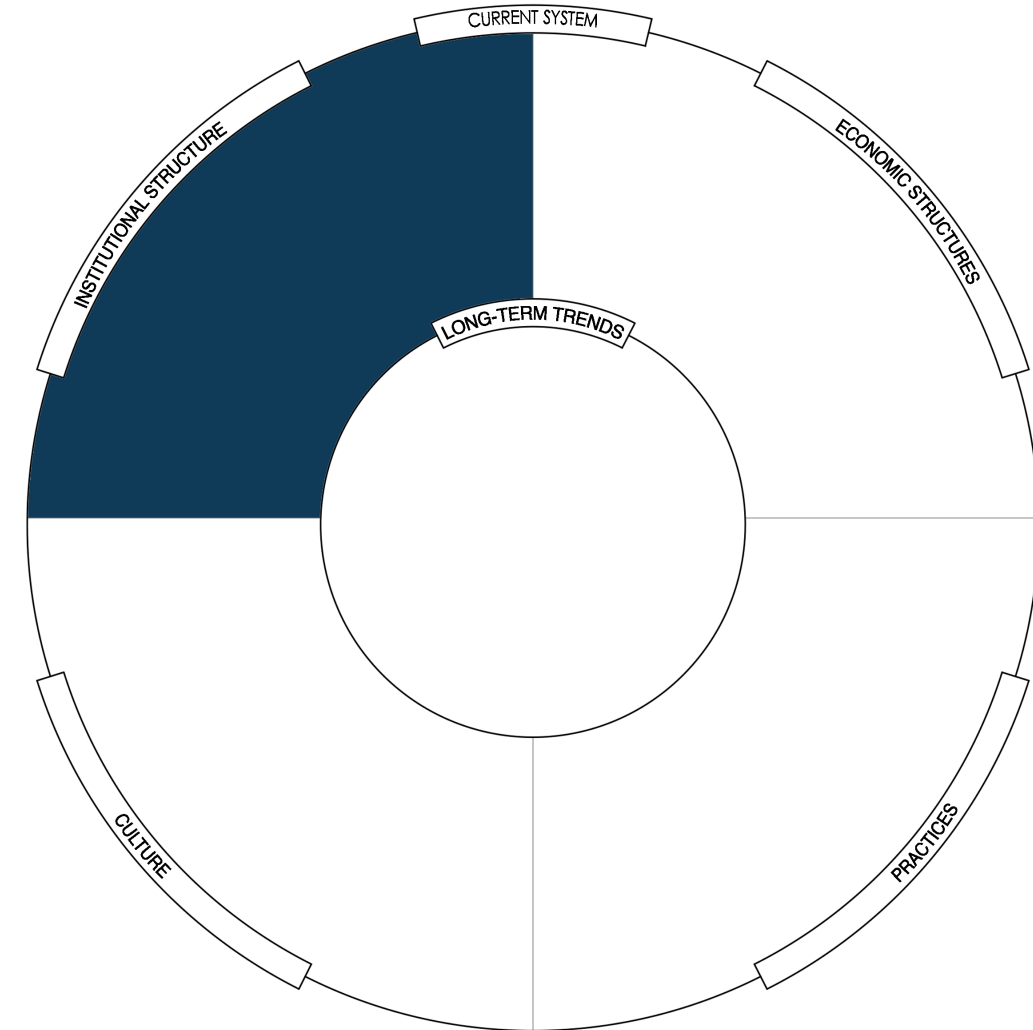


Figure 5: Institutional Structure (Rich Context Mapping)

Economic Quadrant

Sustainability Incentives: Encourage the development of remote access technologies that promote sustainability by minimizing travel and resource consumption. For instance, Doing (2020) and Huisman (2020) discuss how telecommuting technologies can reduce the need for physical transportation, thereby reducing carbon emissions and conserving energy.

Economic Benefits: Highlight the economic advantages of reduced ecological effect, such as cost savings and compliance with environmental legislation. McDaniel & Panchanathan (2019) and Sheldrake (2021) provide examples of companies that have realized significant cost savings through energy-efficient operations. Additionally, they discuss how compliance with environmental regulations can prevent costly fines and enhance a company's reputation.

Long-term Investment: Encourage investment in technologies that put long-term sustainability ahead of short-term economic rewards. Wohlleben (2016) and Head, Atchison, & Phillips (2014) argue for a shift in investment strategies towards technologies that may not offer immediate returns but contribute to long-term sustainability. This could include renewable energy technologies or waste reduction systems.

Balanced Development: Ensure that the development of engaging plant-based technology is balanced with the requirement for sustainable practices that help the environment over time.

Mescher & De Moraes (2014), Calvo, Sahi, & Trewavas (2017), Das (2023), and Chang et al. (2022b) emphasize the need for a balanced approach that considers both technological innovation and environmental impact. They provide examples of plant-based technologies that have been developed with sustainability in mind, such as biofuels and plant-based plastics.

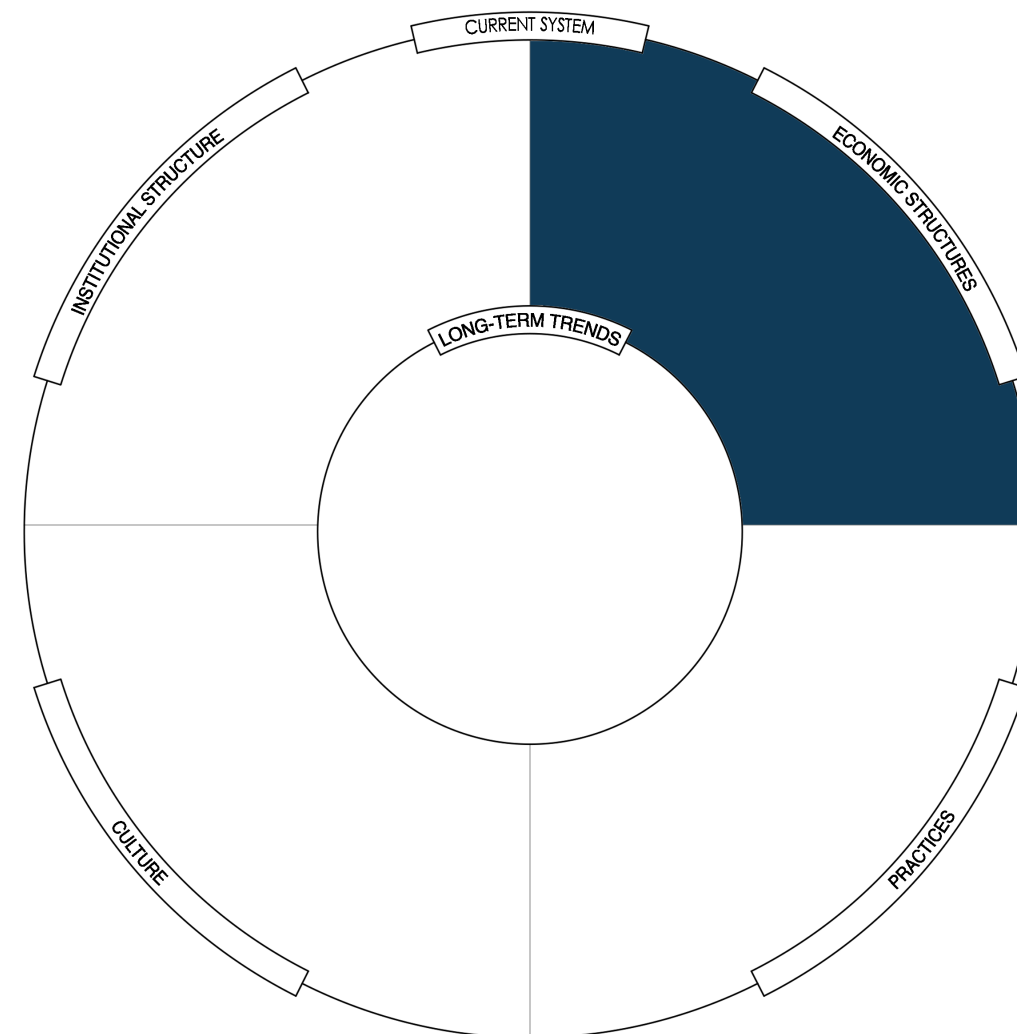


Figure 6: Economic Structure (Rich Context Mapping)

Cultural Quadrant

Promoting Direct Engagement: The importance of creating cultural activities that foster direct engagement with nature is increasingly recognized. This is in response to concerns about the potential alienation caused by technology. For instance, Doing (2020) and Huisman (2020) have explored how immersive experiences in nature can counteract feelings of disconnection and promote a deeper understanding of our environment.

Valuing Complexity: There's a growing trend towards educating and raising awareness about the intricate complexity of natural ecosystems. This is aimed at fostering a greater appreciation and understanding of nature. Studies by Head, Atchison, & Phillips (2014) and Mescher & De Moraes (2014) highlight the importance of this trend, demonstrating how a deeper knowledge of ecosystems can lead to more sustainable behaviors and attitudes.

Leveraging Natural Affinity: Our inherent cultural affinity for nature is a powerful tool that can be harnessed to develop designs and experiences that are emotionally engaging. Wohlleben (2016) and Sheldrake (2021) have shown how leveraging this natural affinity can enhance our connection to the environment and promote a sense of stewardship.

Encouraging Creative Integration: The integration of technology and natural elements is being promoted in a way that respects nature's essence. This approach is resulting in the creation of new and sustainable cultural activities. Works by McDaniel

& Panchanathan (2019), Calvo, Sahi, & Trewavas (2017), Das (2023), and Chang et al. (2022) provide examples of this trend, showcasing how technology can be used to enhance, rather than detract from, our relationship with nature.

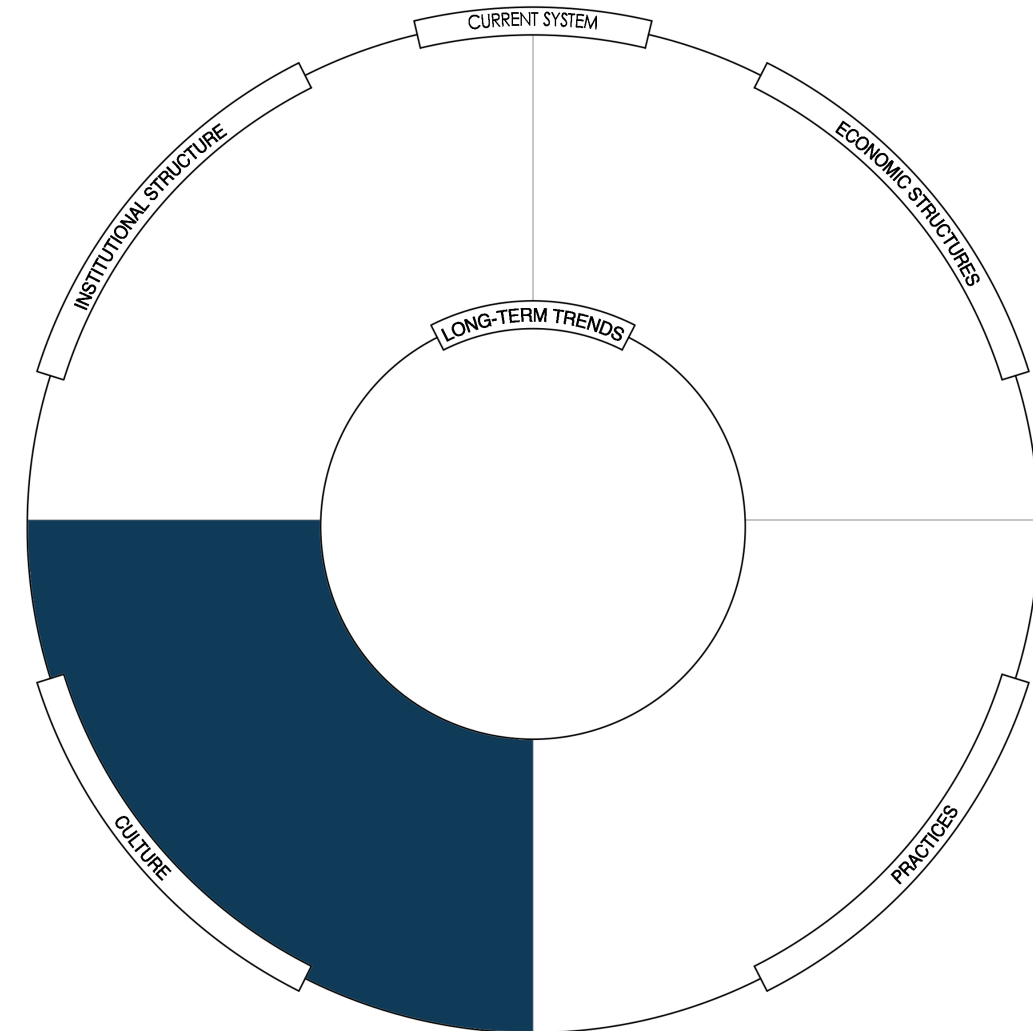


Figure 7: Culture (Rich Context Mapping)

Practices

Interactive Design: The creation of HCI systems that leverage plant stimuli can lead to interactive experiences that not only increase user engagement but also strengthen community relationships. For instance, Chang et al. (2022b) discuss a system where users interact with plants through a digital interface, leading to increased interest and engagement in plant care. Similarly, Doing (2020) highlights a project where community members could interact with a digital representation of a local garden, fostering a sense of community and shared responsibility.

Shared Responsibility: Encouraging designs that foster shared responsibility for plant maintenance can result in increased community contact and collaborative environmental stewardship. Chang et al. (2022b) and Doing (2020) both emphasize the importance of shared responsibility in their studies. They found that when community members felt a shared responsibility for a digital garden, they were more likely to engage in real-world plant care and environmental stewardship activities.

Balanced Mediation: It's important to aim for a balance in technological mediation, ensuring that digital encounters supplement rather than replace physical interactions with plants. McDaniel & Panchanathan (2019) argue that while digital interactions can enhance our understanding and appreciation of plants, they should not replace the tangible, sensory experience of interacting with plants directly.

Sheldrake (2021) and Wohlleben (2016) echo this sentiment, emphasizing the unique benefits of physical interactions with nature.

Direct Experiences: Maintaining opportunities for direct, unmediated experiences with plants is crucial to sustain the sensory and emotional benefits of in-person plant connection. Head et al. (2014) and Mescher & De Moraes (2014) highlight the therapeutic benefits of direct interaction with plants, such as reduced stress and improved mood. Calvo et al. (2017) and Das (2023) further discuss how these benefits can be incorporated into HCI design, promoting wellbeing and connection with nature.

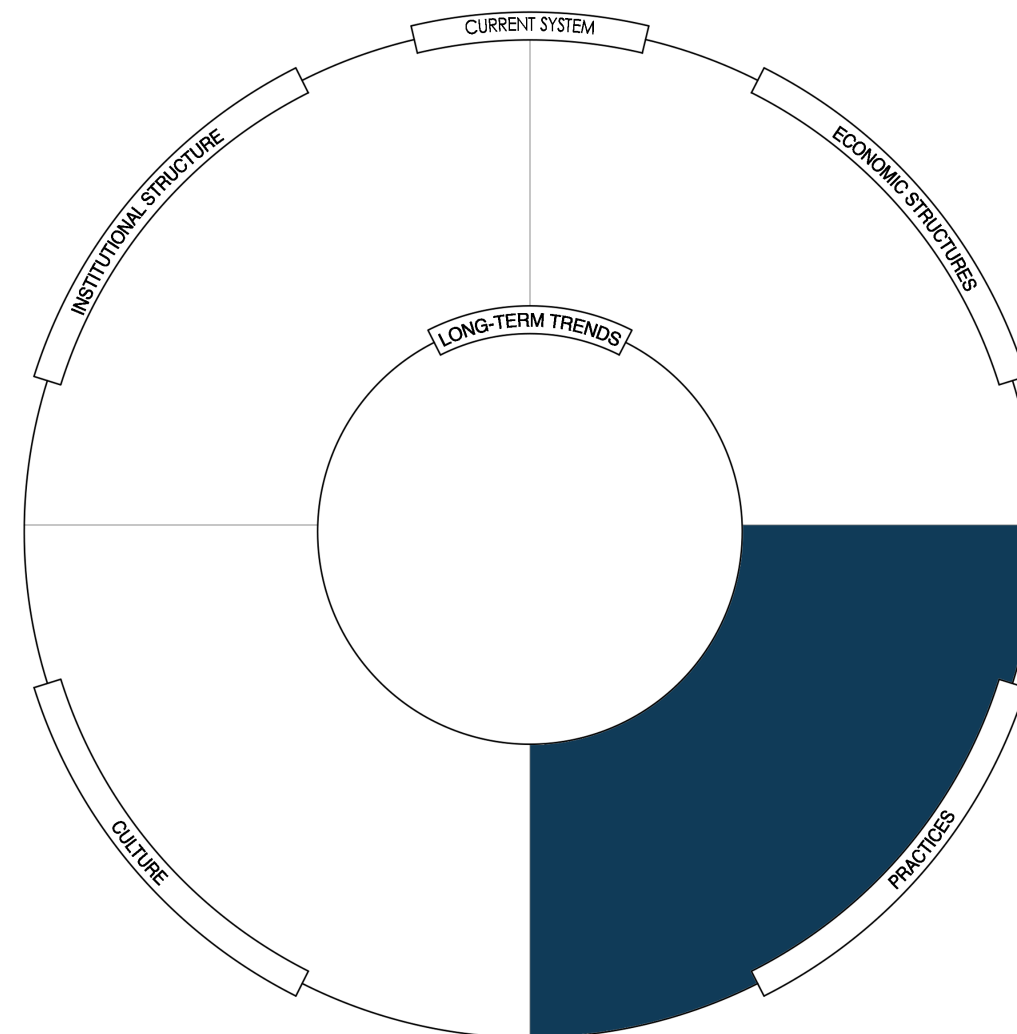


Figure 8: Practices (Rich Context Mapping)

Takeaways from Rich Context Mapping

The rich context mapping exercise has provided a comprehensive understanding of the system and its contexts, highlighting the importance of balancing technological advancements with sustainability and respect for nature (Doing, 2020; Head, Atchison, & Phillips, 2014). It has underscored the significance of social connectivity, well-being, education, and personal enjoyment in the design process (McDaniel & Panchanathan, 2019; Sheldrake, 2021).

Long-term trends indicate a shift towards environmentally conscious behaviors, social connectivity, prioritizing mental and physical health, advancements in education, integration of digital and natural worlds, and the importance of personal enjoyment (Huisman, 2020; Wohlleben, 2016). These trends are shaping the future of interaction design and technology (Chang et al., 2022b).

Institutional policies and ethical criteria need to be developed to balance the benefits of remote technology with the necessity of maintaining a genuine connection to nature (Calvo, Sahi, & Trewavas, 2017). Awareness and education about the necessity of sustaining ecosystem complexity and the ethical implications of distant technology use are crucial (Mescher & De Moraes, 2014).

Economic incentives for sustainability, highlighting economic benefits of reduced ecological impact, encouraging long-term investment in sustainable technologies, and ensuring balanced development are key factors in the economic quadrant (Das, 2023).

Cultural activities that foster direct engagement with nature, valuing the complexity of natural ecosystems, leveraging our inherent cultural affinity for nature, and encouraging creative integration of technology and natural elements are important cultural aspects (Sheldrake, 2021).

In practice, creating HCI systems that leverage plant stimuli for interactive experiences and designs that foster shared responsibility for plant maintenance are encouraged (Doing, 2020; Huisman, 2020).

In conclusion, the future of interaction design and technology is heading towards a more sustainable, socially connected, and nature-integrated direction. It is crucial to balance the benefits of these advancements with the importance of maintaining a genuine connection with nature, prioritizing well-being, and fostering a culture of sustainability and respect for the environment (Chang et al., 2022b). This will ensure that the development of technology enhances our lives while also preserving the world we live in (Wohlleben, 2016).

Relevance to the research questions

Tactile Interactions vs Remote Relationships: It emphasizes the importance of maintaining a genuine connection with nature, even as we advance in technology (Doing, 2020). This suggests that while remote interfaces may offer certain benefits, they may not fully replicate the physiological effects on plant growth (Huisman, 2020) and psychological impacts on human well-being that tactile interactions with live plants can provide (McDaniel & Panchanathan, 2019).

Emotional and Psychological Effects of Physical Touch: It highlights the significance of personal enjoyment, social connectivity, and well-being in the design process (Sheldrake, 2021). This aligns with the research question about the emotional and psychological effects of physical touch with plants on human well-being, especially in the context of increasing prevalence of remote interfaces (Wohlleben, 2016).

Comparison of Physiological and Psychological Responses: It underscores the need for balanced development of engaging plant-based technology with sustainable practices (Head, Atchison, & Phillips, 2014). This suggests a recognition of the different experiences facilitated by physical interactions with plants versus remote interaction technology (Mescher & De Moraes, 2014). It implies that while technology can enhance our lives, it's crucial to ensure it doesn't lead to a disconnection from the natural environment (Calvo, Sahi, & Trewavas, 2017; Das, 2023; Chang et al., 2022).

Step-2: Casual Layered Analysis

In the realm of understanding complex systems and their underlying causes, various methods and metaphors have been employed. One such metaphor is the iceberg for Causal Layered Analysis (Inayatullah, 2004), which, while effective in some respects, falls short in others. The iceberg metaphor, with its hidden bulk beneath the surface, is often used to illustrate how the most significant aspects of a system are not immediately visible. However, this metaphor lacks the ability to adequately represent the dynamic and interconnected nature of systemic layers.

This is why I adapted the Causal Layered Analysis (CLA) method and created a new metaphor - the structure of a tree. This metaphor not only encapsulates the layered nature of systems but also illustrates the interconnectedness and mutual influence of these layers.

In this tree metaphor for CLA, each part of the tree represents a distinct aspect of causality:

In causal layered analysis (CLA), the structure of a tree serves as a powerful metaphor for understanding the different layers of causality. Each part of the tree represents a distinct aspect of CLA:

The Crown - Litany: The crown of the tree, with its leaves and branches reaching towards the sky, symbolizes the 'litany' layer of CLA. This is the visible level of facts, data, and perceived issues. Much like the leaves that may rustle with the wind,

this layer is subject to change and can be easily swayed by external forces.

The Branches - Systems: The branches, which support the crown, represent the 'systems' layer. They are the structures and institutions that hold up and shape the patterns of the litany. These branches are not as easily moved as the leaves, indicating the more complex and less visible systemic causes behind the immediate problems.

The Bark - Worldview: Encasing the trunk, the bark stands for the 'worldview' layer. It is the protective layer of beliefs, cultures, and values that give form to the systems. The bark, with its textured patterns, symbolizes the narratives and ideologies that inform how we interpret our world.

The Roots - Myth/Metaphor: Finally, the roots of the tree delve deep into the ground, embodying the 'myth/metaphor' layer. These are the foundational stories, myths, and unconscious metaphors that underpin and give rise to the worldviews. Often unseen, they are the deepest drivers of why societies are structured the way they are and why people believe what they do.

By using the tree structure as a metaphor for CLA, we can better visualize and understand the interconnectedness of these layers. From the visible litanies to the deep-rooted myths, each part plays a crucial role in shaping the reality we experience.

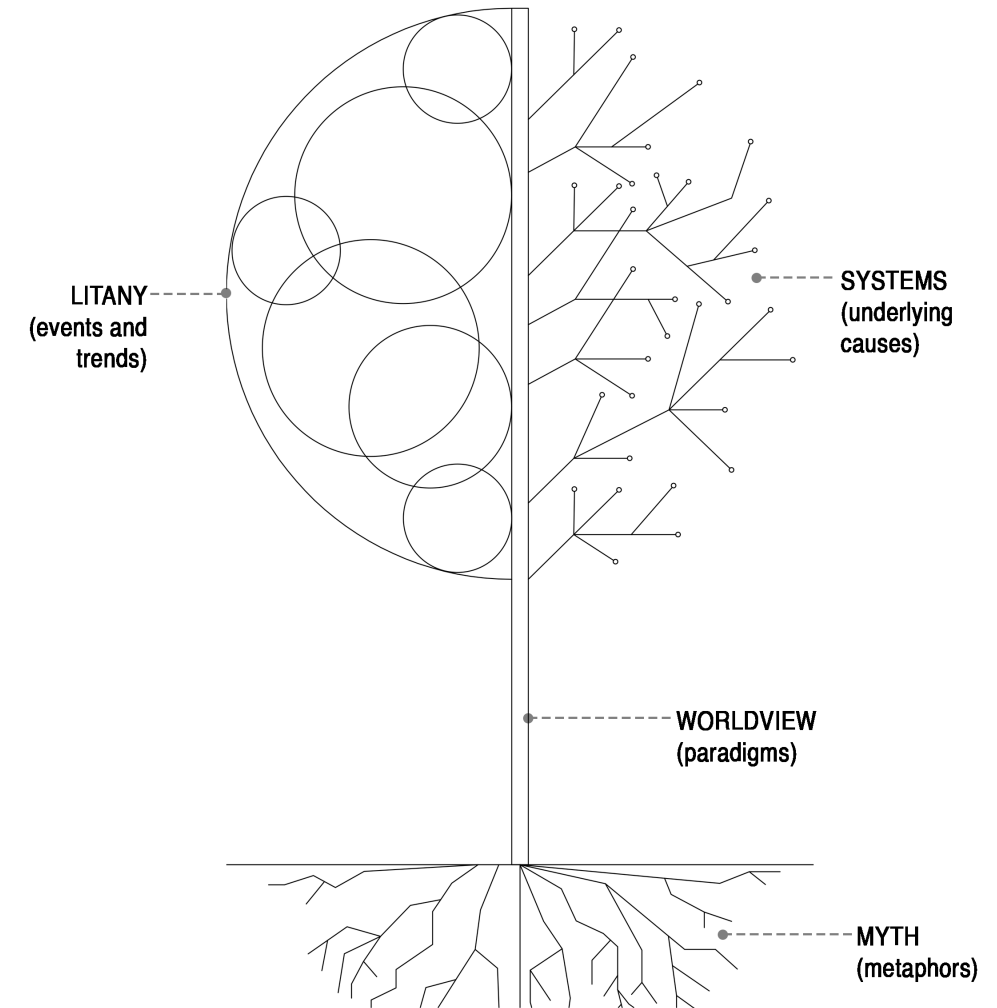


Figure 9: Tree Structure as a metaphoric representation of Causal Layered Analysis

Litany:

This level focuses on the tangible and visible features. For instance, plants are being employed as substitutes for natural environments (Adamatzky, 2014; Harris, 2020). This means that instead of creating artificial environments, researchers are exploring ways to use plants to create a more natural setting. This approach has been found to trigger positive human reactions such as relaxation and stress reduction (Cho et al., 2015; Huisman, 2020). Furthermore, plants are being used as interfaces for different functions such as air purification and aesthetic enhancement (Chang et al., 2022; Hammerschmidt et al., 2015).

The advantages of this approach include distant comfort, which refers to the psychological benefits of being in a plant-filled environment even when physically distant from nature (Degraen et al., 2021). It also leads to a diminished ecological footprint as it reduces the need for artificial materials and energy consumption (Blevis, 2007; Hansson et al., 2021). Moreover, it has been found to improve human experiences by enhancing mood and productivity (Bagalkot, Byrne, & Devendorf, 2018; Hsu et al., 2018), and increase community involvement by encouraging communal care for the plants (Fa et al., 2020).

However, there are obstacles to consider. These include a potential disconnection from the natural world as people may start to see plants only as functional tools rather than living organisms (Forlano, 2017). There's also a risk of oversimplification,

failing to acknowledge the intricacies of natural ecosystems (Coulton & Lindley, 2019). Ethical dilemmas may arise, such as the potential exploitation of plants (Calvo, Sahi, & Trewavas, 2017). Lastly, there's the issue of over-reliance on technology, which may lead to unforeseen consequences such as technological malfunctions affecting plant health (Fell, Greene, Wang, & Kuo, 2020).

Recent research has also explored the potential effects of audible sound signals, including music, on plants as a new trigger for growth and health (Das, 2023). Additionally, the genetic creation of bioluminescent plants for urban and domestic use is an emerging area of research, offering the possibility of natural, energy-efficient lighting solutions (Estévez & Dollens, n.d.).

The importance of Indigenous Peoples' lands for the conservation of Intact Forest Landscapes is a significant consideration in this context. These lands often harbor rich biodiversity and play a crucial role in carbon sequestration (Fa et al., 2020). The concept of 'more-than-human' centered design is being explored to consider other things beyond human needs, acknowledging the intrinsic value of non-human life forms (Coulton & Lindley, 2019). The idea of posthumanism and design is also being discussed to rethink our relationship with the natural world, challenging anthropocentric views and promoting a more holistic, interconnected understanding of life (Forlano, 2017).

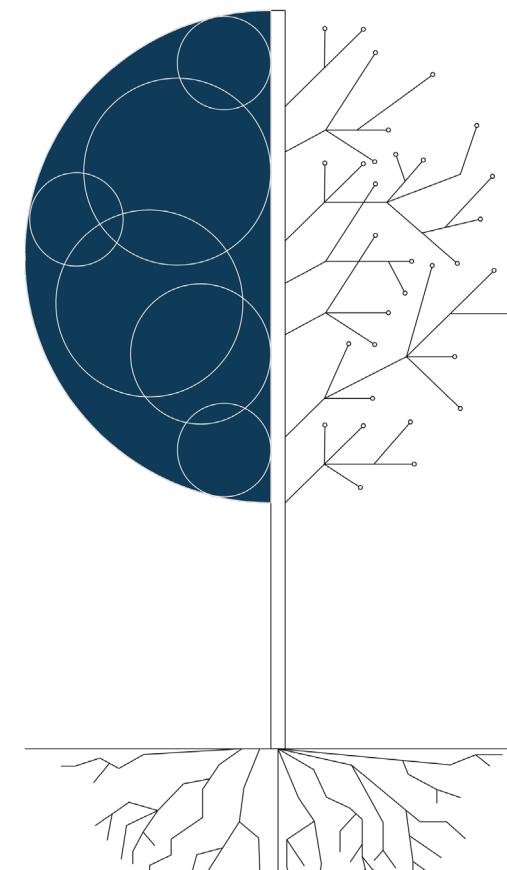


Figure 10: Litany based on literature review

Innovative approaches being explored include the development of wearable sensors for plant health monitoring, which could provide real-time data on plant health and help detect diseases early (Lee, Wei, & Zhu, 2021). The role of plant sensory perception in plant-animal interactions is also being studied, shedding light on the complex communication mechanisms in nature (Mescher & De Moraes, 2014).

Other areas of interest include the evolved control of natural plants, which involves manipulating plant growth and behavior for specific purposes (Hofstadler et al., 2017), and the development of compliant plant wearables for localized microclimate and plant growth monitoring, which could contribute to precision agriculture and urban farming (Nassar et al., 2018).

Social Causes:

The social causes underlying the litany can be traced back to several societal trends and phenomena.

Urbanization and Technological Advancement: The increasing urbanization and technological advancement have led to a disconnection from the natural world (Forlano, 2017). For instance, as cities grow and technology becomes more pervasive, people are spending less time in natural environments and more time in artificial ones. This shift has resulted in the substitution of natural environments with plants in urban settings (Adamatzky, 2014; Harris, 2020), creating a disconnect between humans and nature.

Rise of Human-Centered Design: The rise of human-centered design has also contributed to this trend. This design philosophy focuses on human needs and experiences at the expense of other living beings (Coulton & Lindley, 2019; Fell, Greene, Wang, & Kuo, 2020). As a result, it often overlooks the complexities and intricacies of plant life, leading to ethical dilemmas and a failure to acknowledge the intricacies of plant life (Calvo, Sahi, & Trewavas, 2017).

Reliance on Technology: The reliance on technology for comfort and improved experiences has also played a role (Degraen et al., 2021; Hsu et al., 2018). However, this reliance on technology has had some positive effects as well. It has resulted in a diminished ecological footprint and increased

community involvement (Blevis, 2007; Hansson et al., 2021; Fa et al., 2020), as people are using technology to engage with their communities and reduce their impact on the environment.

More-Than-Human Centered Design: In response to these trends, there has been an exploration of 'more-than-human' centered design and posthumanism in design. These approaches aim to consider other things beyond human needs and rethink our relationship with the natural world (Coulton & Lindley, 2019; Forlano, 2017). For example, designers are now considering how their designs can benefit not just humans, but also the plants and animals that share our environments.

Emerging Research in Plant Capabilities: Emerging research in plant health monitoring, bioelectricity production from plants, and the evolved control of natural plants are indicative of the societal interest in harnessing plant capabilities for human benefit (Lee, Wei, & Zhu, 2021; Lu et al., 2020; Hofstadler et al., 2017). These studies show that society is beginning to recognize the potential benefits of integrating plants into our technological systems.

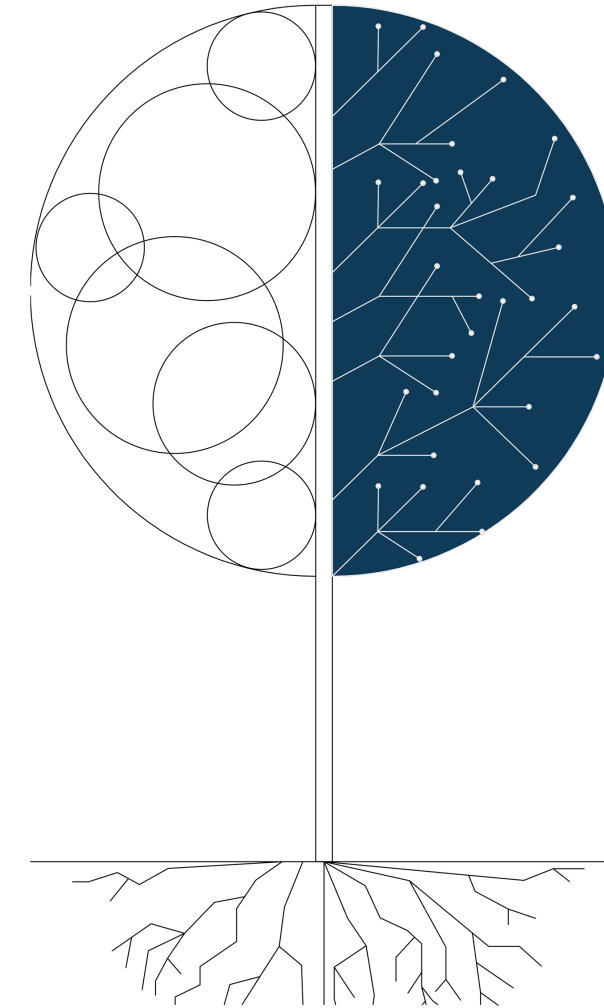


Figure 11: Social Causes based on literature review

Worldview:

The worldview underlying the litany and social causes is rooted in an anthropocentric perspective that prioritizes human needs and experiences over other forms of life (Coulton & Lindley, 2019; Fell, Greene, Wang, & Kuo, 2020). This is evident in the increasing urbanization and technological advancement that have led to a disconnection from the natural world (Forlano, 2017). For instance, the rapid urbanization has led to the destruction of natural habitats, and the rise of technology has created a society where people spend more time interacting with screens than with nature.

However, this anthropocentric worldview is being challenged by emerging perspectives that advocate for a more balanced relationship between humans and the natural world. The concept of 'more-than-human' centred design and posthumanism in design represent a shift towards a more inclusive worldview that acknowledges the intrinsic value of all forms of life (Coulton & Lindley, 2019; Forlano, 2017). For example, 'more-than-human' design principles advocate for considering the needs and experiences of non-human entities in the design process, leading to solutions that benefit both humans and the environment.

The exploration of plant capabilities for human benefit also reflects a utilitarian worldview, where plants are seen as resources to be harnessed for human benefit (Lee, Wei, & Zhu, 2021; Lu et al., 2020; Hofstadler et al., 2017). This is evident in

practices such as deforestation for timber or agricultural purposes. However, this utilitarian perspective is being questioned by research that highlights the ethical dilemmas associated with such an approach (Calvo, Sahi, & Trewavas, 2017). For instance, the overexploitation of plant resources can lead to biodiversity loss and ecosystem imbalance.

The worldview section of the analysis thus reveals a tension between anthropocentric, utilitarian, and more inclusive worldviews, shaping the human-plant interactions. This tension is a key trend in the discourse on human-plant relationships, with implications for how we design and interact with our environment.

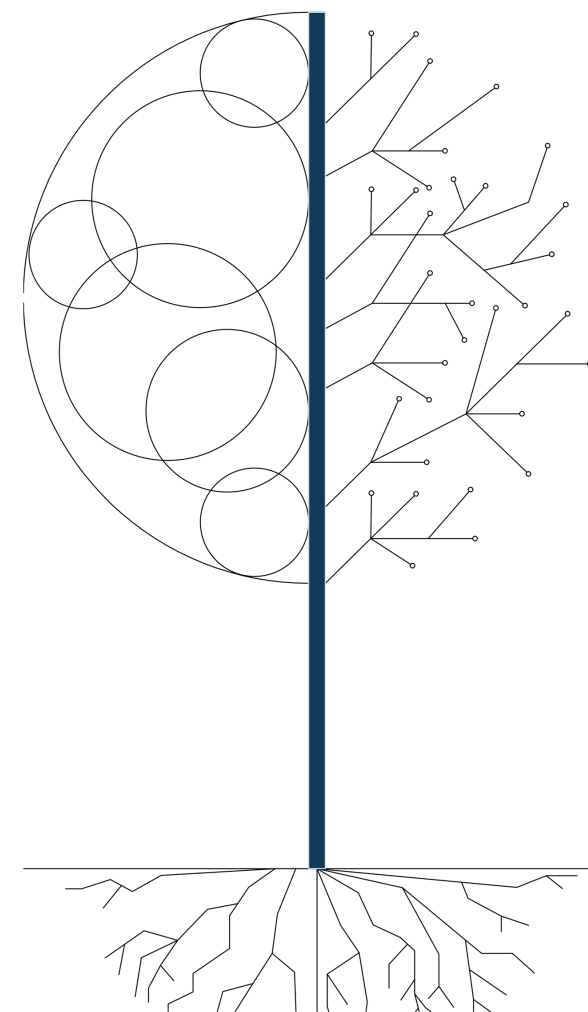


Figure 12: Worldview based on literature review

Myth/Metaphor:

The prevailing metaphor of “plants as machines” (Hammerschmidt et al., 2015; Hofstadler et al., 2017) is deeply rooted in our societal narrative. This metaphor reflects an anthropocentric and utilitarian worldview, where plants are seen as resources to be harnessed for human benefit (Lee, Wei, & Zhu, 2021; Lu et al., 2020). For instance, plants are often engineered for higher yield or resistance to pests, treating them as if they were mechanical entities designed for human use.

However, this metaphor is being challenged by the emerging metaphor of “plants as sentient beings” (Calvo, Sahi, & Trewavas, 2017; Mescher & De Moraes, 2014). This shift is not merely semantic but represents a fundamental change in how we perceive and interact with the plant world. It acknowledges the intrinsic value and capacities of plants (Head, Atchison, & Phillips, 2014), recognizing their ability to respond to environmental stimuli, communicate with each other, and even exhibit forms of learning and memory.

The metaphor of “plants as interfaces” (Chang et al., 2022; Huisman, 2020) is also gaining traction, reflecting the trend of employing plants for various functions in human-computer interaction. This metaphor sees plants not just as passive objects but as active participants in our digital lives, capable of sensing, processing, and responding to information in ways that can enhance our technological experiences.

In summary, the analysis of these metaphors reveals a significant shift in our societal narrative about plants. We are moving away from viewing plants as passive objects to be exploited, towards recognizing them as active subjects with their own capacities and value. This shift has profound implications for how we interact with the plant world and how we might design our technologies and societies in the future.

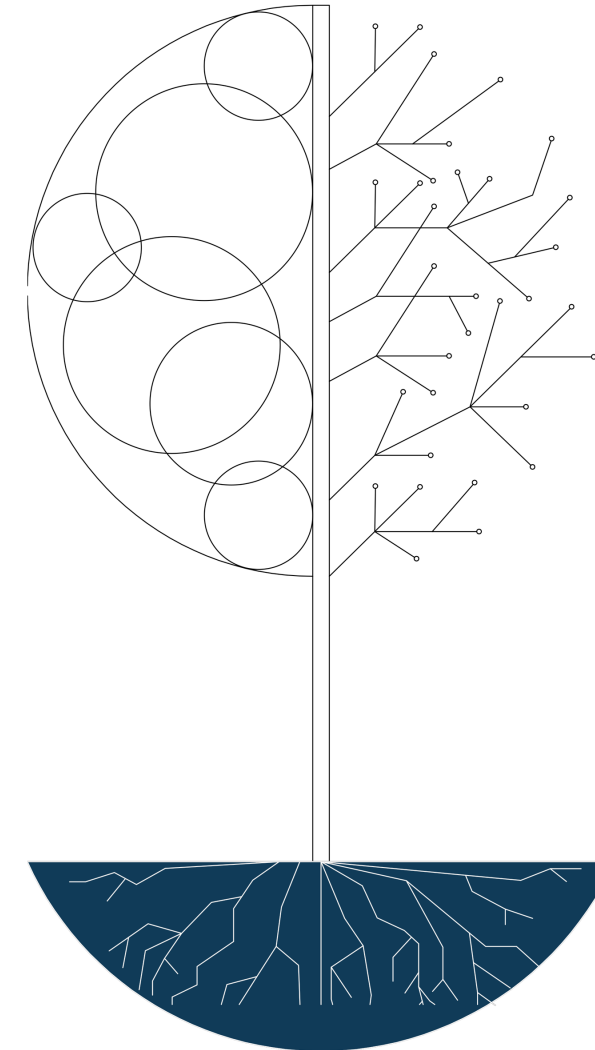


Figure 13: Myth/Metaphor based on literature review

Takeaways from Causal Layered Analysis

The Causal Layered Analysis reveals a dominant anthropocentric worldview that prioritizes human needs and experiences over other forms of life (Coulton & Lindley, 2019; Fell, Greene, Wang, & Kuo, 2020). This worldview, reflected in the increasing urbanization and technological advancement, has led to a disconnection from the natural world (Forlano, 2017). However, there is an emerging shift towards a more inclusive worldview that acknowledges the intrinsic value of all forms of life. This shift is represented by the concept of ‘more-than-human’ centered design and posthumanism in design (Coulton & Lindley, 2019; Forlano, 2017).

The prevalent utilitarian perspective, where plants are seen as resources to be harnessed for human benefit, is evident (Lee, Wei, & Zhu, 2021; Lu et al., 2020; Hofstadler et al., 2017). Yet, this perspective is being questioned by research that highlights the ethical dilemmas associated with such an approach (Calvo, Sahi, & Trewavas, 2017).

The metaphor of “plants as machines” is dominant, reflecting the anthropocentric and utilitarian worldview (Hammerschmidt et al., 2015; Hofstadler et al., 2017). However, the emerging metaphor of “plants as sentient beings” represents a shift towards a more inclusive worldview that acknowledges the intrinsic value and capacities of plants (Calvo, Sahi, & Trewavas, 2017; Mescher & De Moraes, 2014).

The exploration of plant capabilities for human benefit and the development of compliant plant

wearables for localized microclimate and plant growth monitoring are indicative of the societal interest in harnessing plant capabilities (Lee, Wei, & Zhu, 2021; Lu et al., 2020; Hofstadler et al., 2017; Nassar et al., 2018).

This highlights the complex interplay of societal trends, technological advancements, and ethical considerations shaping the human-plant interactions. They underscore the need for a shift in worldview and metaphors to foster a more balanced and respectful relationship with the natural world.

Relevance to the research questions

The analysis highlights the increasing use of plants as substitutes for natural environments and interfaces for different functions (Adamatzky, 2014; Harris, 2020; Chang et al., 2022). This suggests that tactile interactions with live plants and technologically mediated remote relationships may have different physiological effects on plant growth and psychological impacts on human well-being. The exploration of plant capabilities for human benefit and the development of compliant plant wearables for localized microclimate and plant growth monitoring are indicative of the societal interest in harnessing plant capabilities (Lee, Wei, & Zhu, 2021; Lu et al., 2020; Hofstadler et al., 2017; Nassar et al., 2018).

It underscores the emotional and psychological effects of physical touch with plants on human well-being. The concept of ‘more-than-human’ centred design and posthumanism in design represent a shift towards a more inclusive worldview that acknowledges the intrinsic value of all forms of life (Coulton & Lindley, 2019; Forlano, 2017). However, the increasing prevalence of remote interfaces has led to a disconnection from natural environments (Forlano, 2017), which may impact these emotional and psychological effects.

It reveals a tension between anthropocentric, utilitarian, and more inclusive worldviews, shaping the human-plant interactions (Coulton & Lindley, 2019; Fell, Greene, Wang, & Kuo, 2020; Forlano, 2017). This suggests that specific physiological

responses experienced by individuals when physically interacting with plants utilized as live display mediums may differ from the experiences facilitated by remote interaction technology.

Step - 3: Horizon Scanning

The Three Horizons Method is a powerful framework for managing innovation and planning strategic growth. This method allows organizations to discuss their current strategies (Horizon 1), emerging innovations (Horizon 2), and long-term future growth (Horizon 3) in a structured manner. The three overlapping horizon curves provide a heuristic for determining the strategic fit of actions chosen to promote a desired future vision, versus a continuation of default 'business as usual' or non-desired outcomes. This idea challenges the conventional linear perception of time and progress, suggesting a more fluid and multifaceted understanding of the future (Baghai et al., 1999). However, the traditional representation of this method with three curves may not resonate with everyone.

To make this concept more relatable and intuitive, I have adapted the Three Horizons Method into a new metaphor - the stages of germination. This metaphor not only aligns with the principles of the Three Horizons Method but also provides a fresh perspective for understanding and applying the method.

The germination metaphor provides a tangible and intuitive way to comprehend the transition from current practices to future aspirations. It emphasizes the importance of nurturing emerging innovations, much like the cotyledons nourish the plant until it can sustain itself. This perspective encourages organizations to invest in and support innovative

ideas that may seem small or insignificant now but have the potential to drive significant growth and change in the future.

Moreover, this approach underscores the continuous nature of innovation and growth. Just as a plant doesn't stop growing after germination, an organization should continually strive for innovation and improvement, even after achieving its immediate goals.

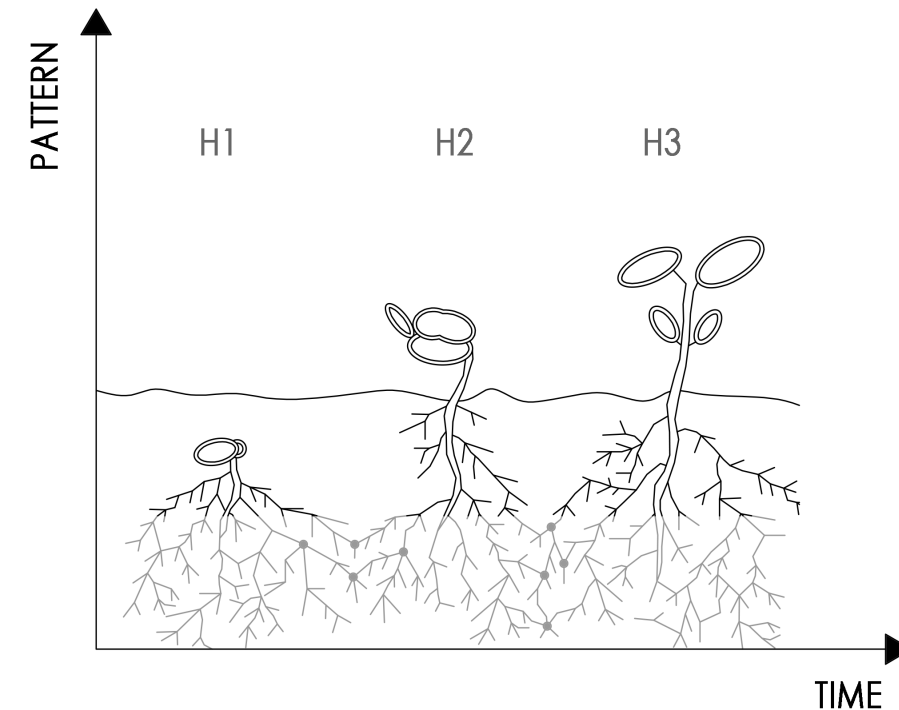


Figure 14: Stages of germination as a metaphoric representation of Horizon Scanning

The stages of germination align with the Three Horizons:

First Horizon (H1) - Radicle: Just as the radicle is the first part of a seedling to emerge during germination, it represents the existing systems and structures. It's the initial growth that anchors the plant, much like current practices anchor an organization.

Second Horizon (H2) - Cotyledon Development: The cotyledons, or seed leaves, provide the nutrients the plant needs to grow until it can produce its own food through photosynthesis. This stage represents emerging innovations that challenge and feed the transition from the old to the new, providing the necessary support for growth and change.

Third Horizon (H3) - Plumule Development: The plumule, which will eventually become the shoot, represents the future growth of the plant. In the Three Horizons Method, this corresponds to the long-term vision and aspirations of the organization.

In conclusion, the Three Horizons Method, when viewed through the lens of the germination stages, provides a powerful tool for organizations to plan their growth strategically. It allows them to balance their focus between managing current operations efficiently, fostering emerging innovations, and envisioning a future that drives continuous growth and evolution. This balance is crucial for organizations to thrive in a dynamic and competitive business environment. By applying this method

organizations can ensure they are not only reacting to the changes in their environment but also proactively shaping their future.

Horizon 1:(Present to 5 years)

This horizon focuses on the immediate applications and implications of human-plant interactions.

For instance, Adamatzky (2014) explores the possibility of making electrical wires from living plants. This innovative idea is based on the use of lettuce seedlings as a prototype model of a plant wire. The research found that the lettuce seedlings could conduct electricity, opening up the potential for sustainable and biodegradable wiring solutions in the future (Adamatzky, 2014).

Similarly, Cho et al. (2015) investigates people's emotional responses to a plant's emotional expression. This study involved creating a system where plants could "express" emotions through movement and color changes. The results showed that participants had strong emotional responses to these plant expressions, suggesting that plants could play a role in emotional health and well-being (Cho et al., 2015).

Adding to this, Hammerschmidt et al. (2015) introduces InfoPlant, a system that enhances human-computer interaction through multimodal augmentation of plants. InfoPlant uses sensors to detect a plant's physiological responses, which are then translated into computer commands. This allows users to interact with their computers in a more natural and intuitive way, using plants as an interface (Hammerschmidt et al., 2015).

These studies represent key trends in the field of human-plant interactions, demonstrating the potential for plants to play a significant role in technology and emotional health in the near future.

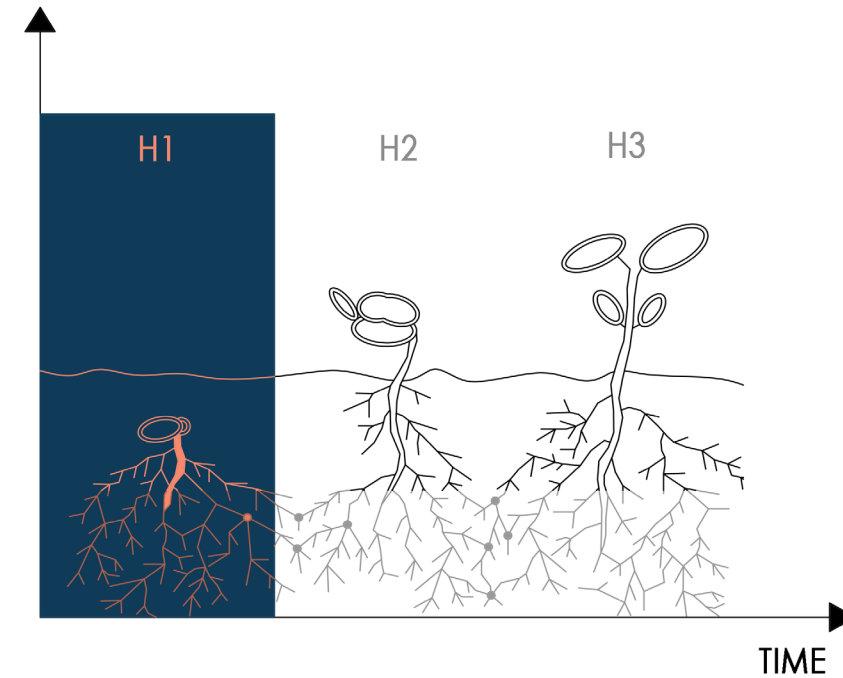


Figure 15: Horizon-1 based on literature review

Horizon 2: (5 to 15 years)

This horizon explores the emerging trends and technologies that are poised to redefine the future of human-plant interactions. For instance, Chang et al. (2022) conducted a comprehensive survey of projects spanning various fields such as HCI, art/design, architecture, and bioengineering.

Their work identified core design paradigms for Human-Plant Interaction (HPI), such as the use of biofeedback in interactive plant systems and the integration of plants in interactive art installations. They also discussed opportunities for future exploration, like the potential of using plants as biosensors or the development of plant-robot hybrids (Chang et al., 2022).

Coulton and Lindley (2019) proposed a paradigm shift towards More-Than Human Centered Design. This approach acknowledges the complex interdependencies of human and non-human actants, emphasizing the need to consider the agency of non-human entities in design processes. For example, they discussed the concept of “entanglement,” where human and non-human entities are intertwined and mutually influential, challenging the anthropocentric view of design (Coulton & Lindley, 2019).

Furthermore, Hansson et al. (2021) provided a comprehensive review of a decade of sustainable HCI. Their work offers insights into the evolution and future directions of this field.

They highlighted the growing emphasis on sustainability in HCI research, with a focus on areas like energy conservation, sustainable consumption, and the design of green technologies. They also pointed out future research directions, such as the need for more longitudinal studies and the exploration of socio-technical systems in the context of sustainability (Hansson et al., 2021).

These works collectively shed light on the key trends shaping the future of human-plant interactions and sustainable HCI, providing a solid foundation for further exploration in these areas.

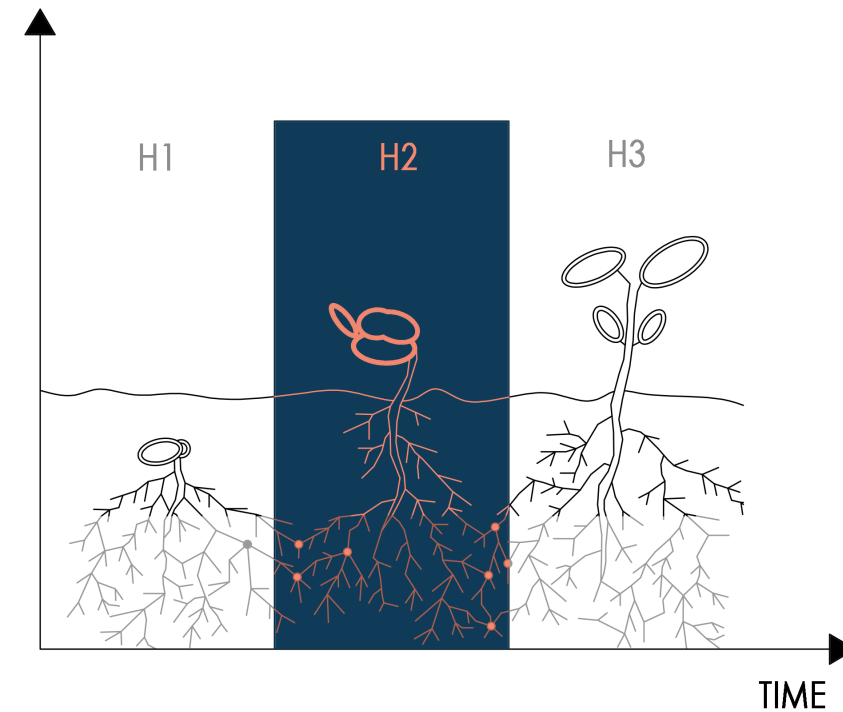


Figure 16: Horizon-2 based on literature review

Horizon 3:(15+ years)

This horizon scans for potential paradigm shifts and transformative technologies. One such shift is the potential effects of audible sound signals, including music, on plants. For instance, Das (2023) discusses how these sound signals could act as a new trigger for plant growth and development. Das's research suggests that certain frequencies and rhythms, particularly those found in music, can stimulate plant cells to increase their metabolic rates, thereby accelerating growth and development (Das, 2023). This could revolutionize agricultural practices and lead to more sustainable farming methods.

The concept of “Grow Your Own Cloud” represents a speculative vision of the future where data is stored and processed in plants. This idea is based on the premise that as we continue to generate vast amounts of data, traditional storage methods may become unsustainable. By harnessing the natural processes of plants, we could create a more eco-friendly and efficient way to store data. This could potentially transform our current data centers into green spaces, reducing our carbon footprint.

Furthermore, Hamann et al. (2017) introduce Flora Robotica, an architectural system that combines living natural plants and distributed robots. This bio-hybrid system is designed to adapt and respond to its environment, much like a living organism. The robots in the system guide the growth of the plants, creating structures that are both functional and aesthetically pleasing.

This offers a glimpse into the future of bio-hybrid architecture, where buildings are not just built, but grown (Hamann et al., 2017). This could lead to more sustainable and resilient urban environments.

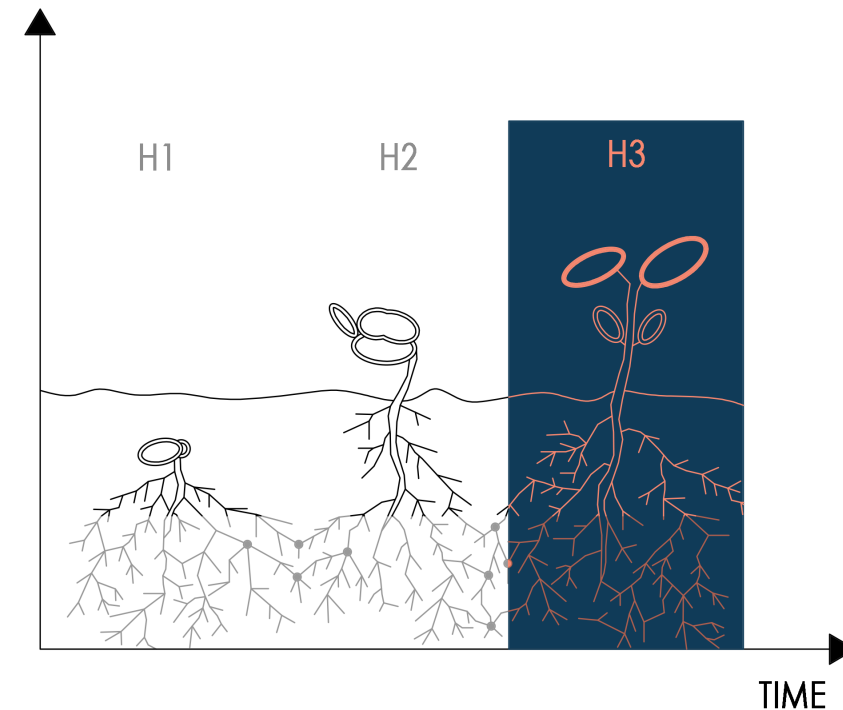


Figure 17: Horizon-3 based on literature review

Takeaways from Horizon Scanning

In Horizon one (Present to 5 years), the focus is on the immediate applications and implications of human-plant interactions. For instance, Adamatzky (2014) is exploring the intriguing possibility of creating electrical wires from living plants, using lettuce seedlings as a prototype model of a plant wire. In a similar vein, Cho et al. (2015) are investigating people's emotional responses to a plant's emotional expression. Adding another dimension to this horizon, Hammerschmidt et al. (2015) have introduced InfoPlant, a system that enhances human-computer interaction through the multimodal augmentation of plants.

Moving on to Horizon two (5 to 15 years), the emerging trends and technologies are likely to shape the future of human-plant interactions. A survey of projects across HCI, art/design, architecture, and bioengineering by Chang et al. (2022) has identified core design paradigms for Human-Plant Interaction (HPI) and discussed opportunities for future exploration. In a significant shift, Coulton & Lindley (2019) propose a move towards More-Than Human Centred Design, considering the complex interdependencies of human and non-human actants. Additionally, a comprehensive review of a decade of sustainable HCI by Hansson et al. (2021) offers insights into the evolution and future directions of this field.

In the third horizon (15+ years), potential paradigm shifts and transformative technologies are being scanned.

For instance, Das (2023) discusses the potential effects of audible sound signals, including music, on plants, suggesting a new trigger for plant growth and development. The concept of "Grow Your Own Cloud" represents a speculative vision of the future where data is stored and processed in plants. Furthermore, Hamann et al. (2017) introduce Flora Robotica, an architectural system that combines living natural plants and distributed robots, offering a glimpse into the future of bio-hybrid architecture.

Relevance to the research questions

Tactile interactions with live plants and technologically mediated remote relationships, the work by Adamatzky (2014) and Hammerschmidt et al. (2015) could be particularly relevant. Adamatzky's exploration of creating electrical wires from living plants (Adamatzky, 2014) suggests that plants can respond to and interact with technological elements, which could have implications for their growth. Hammerschmidt et al.'s InfoPlant system, which enhances human-computer interaction through the multimodal augmentation of plants (Hammerschmidt et al., 2015), could provide insights into the psychological impacts on human well-being in technologically mediated interactions with plants.

The emotional and psychological effects of physical touch with plants, the study by Cho et al. (2015) investigating people's emotional responses to a plant's emotional expression (Cho et al., 2015) could provide valuable insights. This research could help understand how physical interactions with plants might affect human well-being, especially in the context of increasing disconnection from natural environments due to the prevalence of remote interfaces.

On comparing physiological and psychological responses in physical versus remote interactions with plants, the work by Chang et al. (2022), Coulton & Lindley (2019), and Hansson et al. (2021) could be relevant.

Chang et al.'s survey of projects across HCI, art/design, architecture, and bioengineering (Chang et al., 2022) and Coulton & Lindley's proposal for a shift towards More-Than Human Centered Design (Coulton & Lindley, 2019) could provide insights into the design of remote interaction technology and its impact on human experiences. Hansson et al.'s review of a decade of sustainable HCI (Hansson et al., 2021) could offer insights into the evolution of these experiences over time.

Step - 4: Survey Data Results

In this report, I present the findings of a comprehensive survey conducted to understand the impact of green spaces and plant-related activities on individuals' well-being and productivity, particularly in urban and workplace environments. The survey explored various themes such as the importance of green spaces in cities, the impact of plants on stress levels and mindset, the integration of plant-related activities into workplace wellness programs, and the role of these activities in promoting environmental stewardship and awareness. A detailed list of the survey questions can be found in the appendix. The following sections delve into the common themes and patterns I identified through the survey.

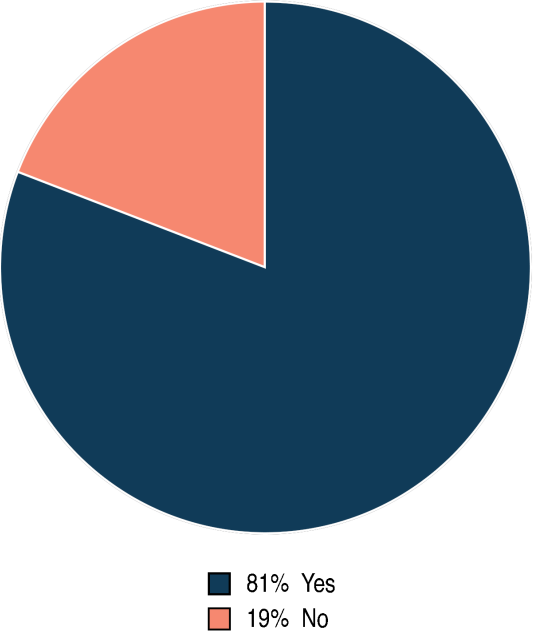


Figure 18: Botanical entities within domestic environments.

A majority of the respondents maintain botanical entities within their domestic environments.

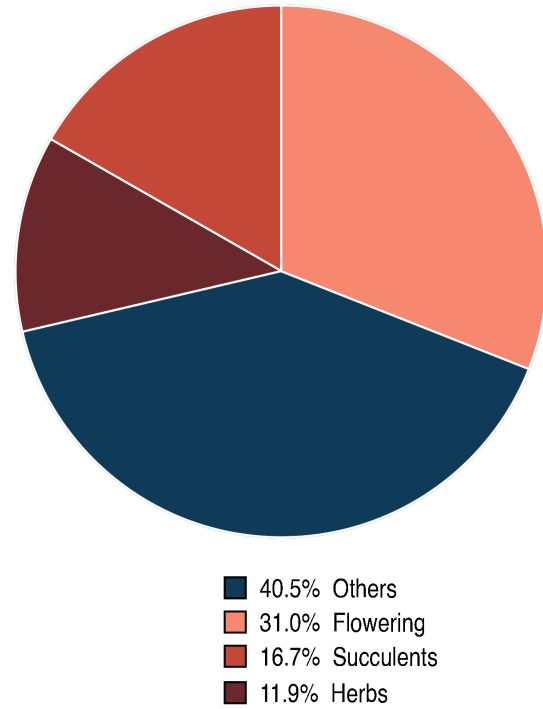


Figure 19: Botanical diversity

Respondents maintain a diverse array of botanical entities, each serving a distinct purpose.

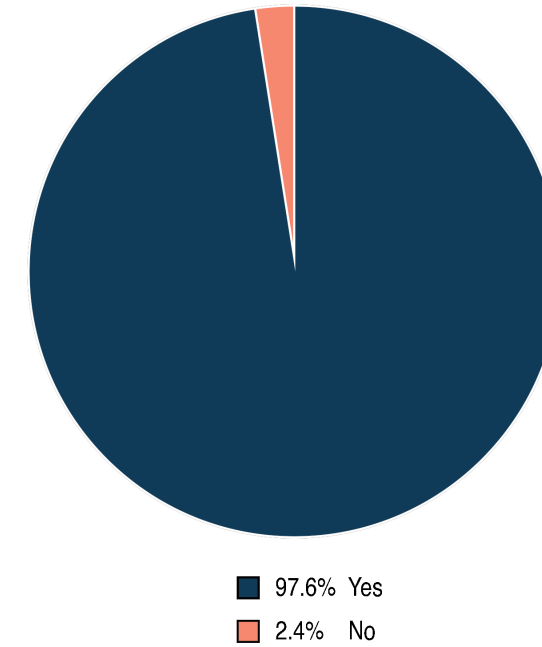


Figure 20: Botanical Presence Boosting Respondents' Well-being and Mood

A significant proportion of respondents believe that the presence of botanical entities enhances their psychological well-being and mood.

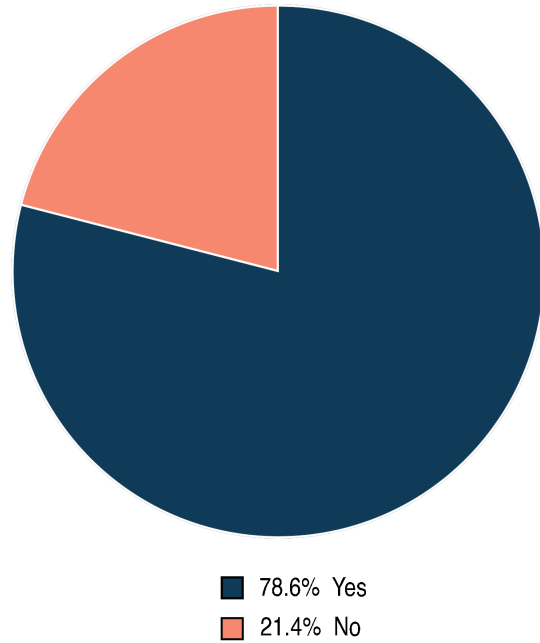


Figure 21: Engagement in horticulture

A substantial 78% of respondents have engaged in horticultural activities.

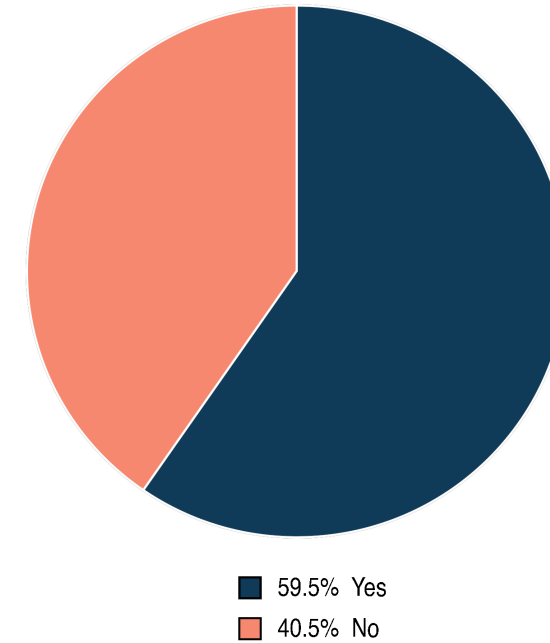


Figure 22: Participation in conservation activities

Approximately 59% of respondents have participated in conservation activities.

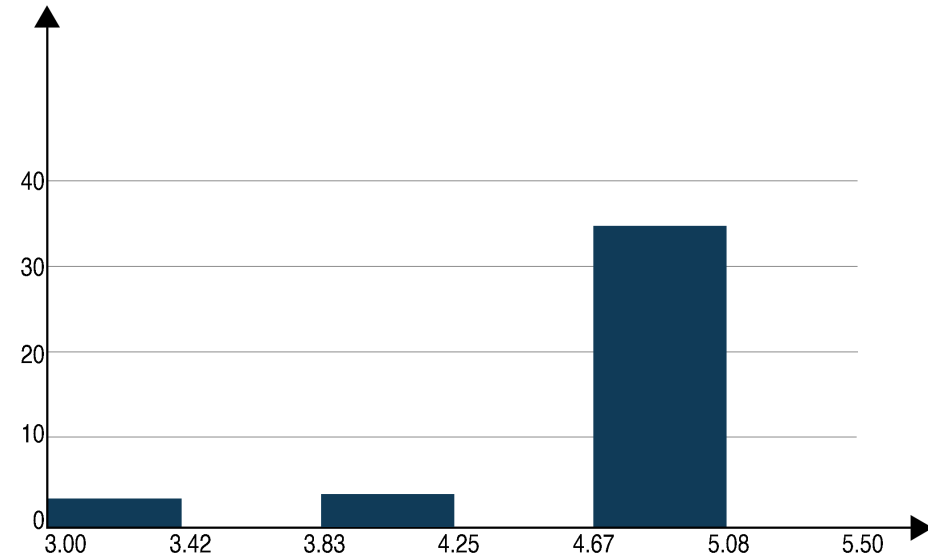


Figure 23: Majority of Respondents View Habitat Protection as Crucial

A majority of respondents deem habitat protection as a crucial endeavor. The statement “A majority of respondents deem habitat protection as a crucial endeavor” is based on the responses to the survey question about the importance of protecting habitats and biodiversity. This statement suggests that most of the people surveyed believe strongly in the importance of this issue.

It reveals a strong public consensus on the importance of habitat protection, highlighting it as a crucial endeavor in our collective responsibility towards environmental stewardship. This consensus is a positive indication of the growing public support for conservation efforts and the broader goal of sustainable development.

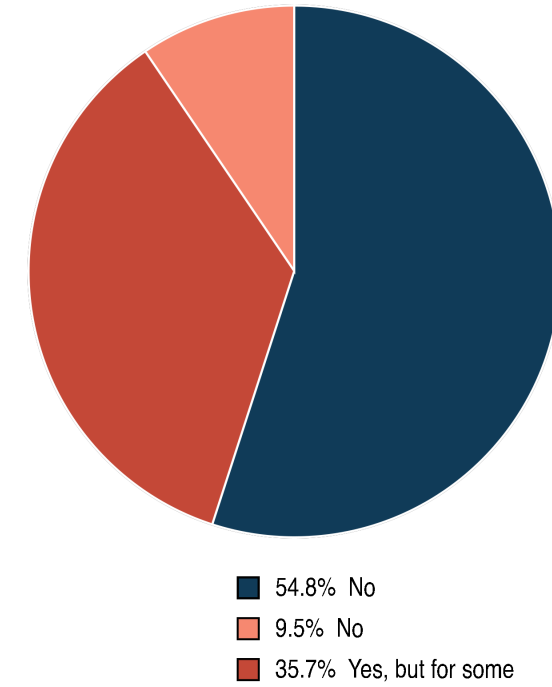


Figure 24: Nature Connection and Green Space Access Among Respondents

While 54.8% of respondents reside in proximity to community or private gardens, thereby facilitating a connection with nature, 35.7% feel a diminished connection despite similar surroundings. A minority

of 9.5% reside in areas devoid of immediate access to green spaces.

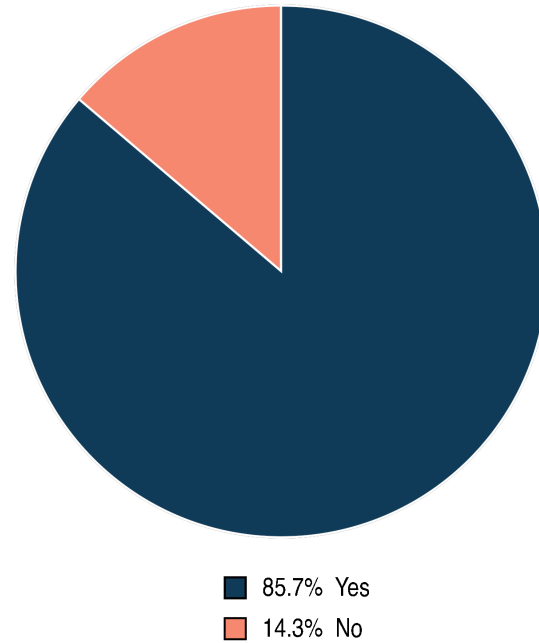


Figure 25: 85.7% of Respondents Use Plant-Based Health Products

A significant 85.7% of respondents have experimented with plant-based remedies and products for health improvement or relaxation.

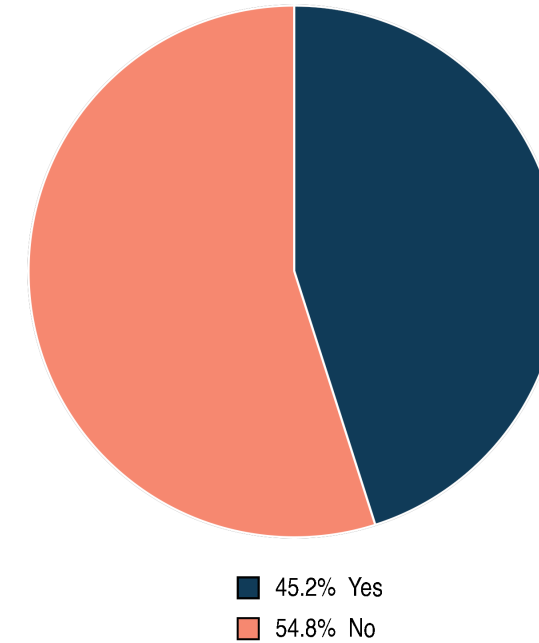


Figure 26: Lack of awareness on ecological impact of plant interactions

Approximately 54.8% of respondents lack awareness about the ecological implications of their daily interactions with plants, including sourcing and disposal.

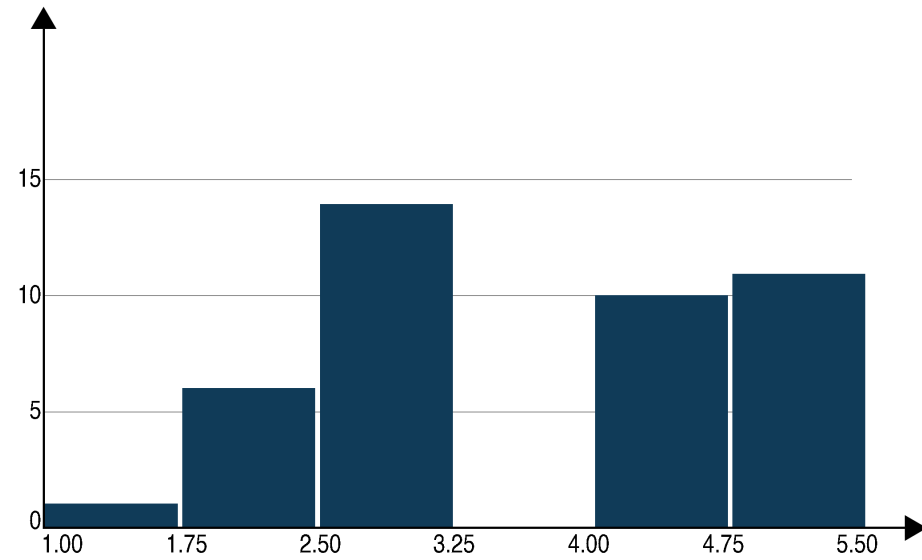


Figure 27: majority of the people feel moderately connected or related plants

The scale ranges from 1 to 5, where: 1 represents the least connection or relationship with plants. This could be interpreted as having little to no interaction or emotional attachment to plants. 5 represents the most connection or relationship with plants. This could mean having a strong emotional bond, frequent interaction, or a deep understanding and appreciation of plants. The response provided was: “Most respondents report a moderate level of connection or relation to plants.” This suggests that the majority of the people surveyed feel a moderate level of connection to plants.

In the context of the scale provided, a “moderate level of connection” likely corresponds to a rating around 3. This indicates that while these individuals may not feel a deep, significant connection to plants (a rating of 4 or 5), they also do not feel disconnected or indifferent towards plants (a rating of 1 or 2). Instead, their relationship with plants is balanced, perhaps characterized by occasional interaction and a general appreciation for plants, but not necessarily a strong emotional bond or deep understanding.

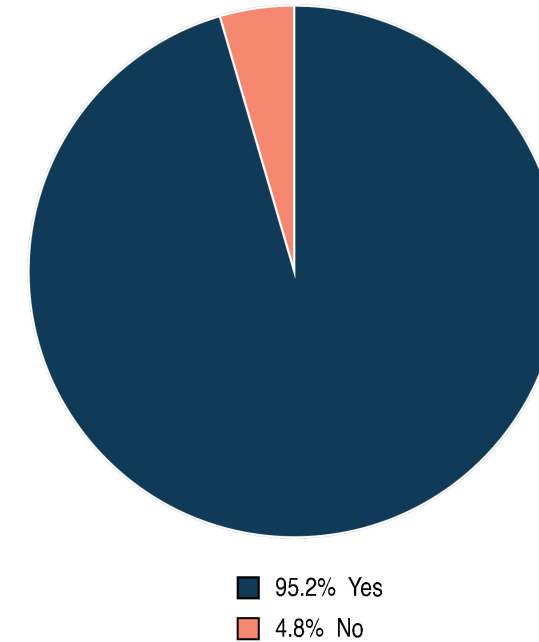


Figure 28: 95.2% Find Plants Foster Positive Workplace Environment

A substantial 95.2% of respondents believe that the presence of plants in the workplace fosters a positive and productive environment.

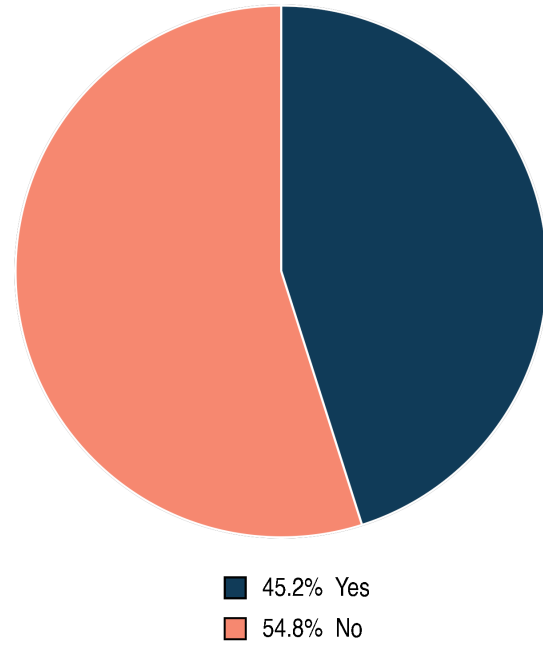


Figure 29: Lack communal of plant care opportunities at work

Approximately 54.8% of respondents have not had the opportunity to engage in communal plant care in their work environment.

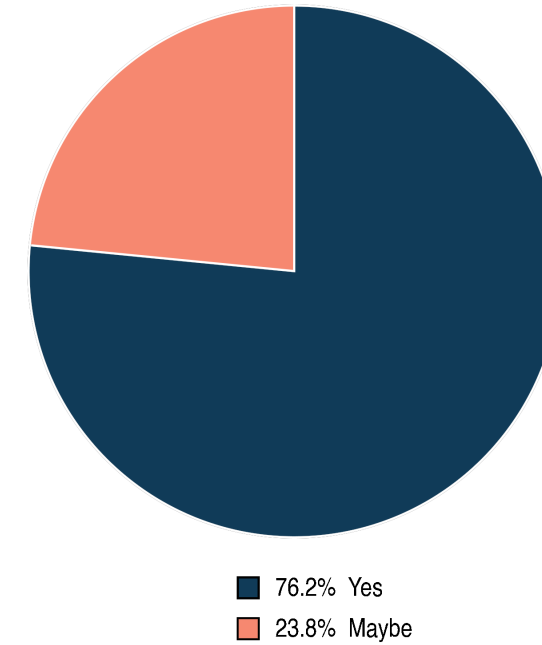


Figure 30: Plants as enhancers of creativity and innovation at work

A majority of 76.2% of respondents believe that the presence of plants in the workspace can enhance creativity and innovation, while 23.8% express uncertainty regarding this.

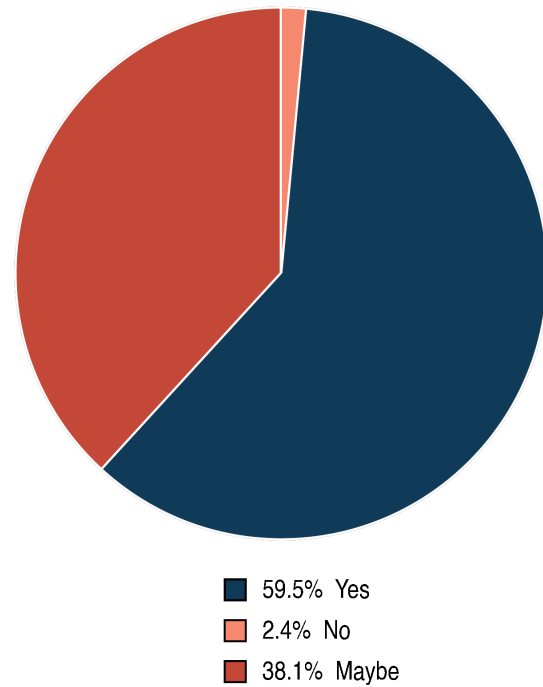


Figure 31: Thoughts on presence plants in co-working spaces

Approximately 59.5% of respondents believe that the presence of plants in co-working spaces enhances interpersonal connections, while 38.1% express uncertainty. A minority of 2.4% do not

believe that the presence of plants in co-working spaces enhances interpersonal connections.

Aspects of gardening that bring the most joy to individuals:

Connection with Nature: Many respondents mentioned a sense of connection with nature as a key aspect of their enjoyment. This includes the act of planting, tending to plants, and seeing them grow.

Calming and Therapeutic Effects: A significant number of responses highlighted the calming and therapeutic effects of gardening.

Learning and Discovery: Some respondents enjoy the learning aspect of gardening, whether it's about the plants themselves or the process of gardening.

Satisfaction from Growth and Results: Many respondents derive satisfaction from seeing their plants grow, bloom, or bear fruit.

Bonding and Shared Activity: For some, gardening is a shared activity that allows for bonding with family members.

Challenges and Dislikes: A few respondents mentioned challenges they faced in gardening or outright stated that they do not enjoy it.

Sensory Enjoyment: Some respondents enjoy the sensory aspects of gardening, such as the smell of plants or the feel of soil.

Caring and Nurturing: Some respondents likened taking care of plants to nurturing a living being, which they find enjoyable.

Survey participants' views on how the existence of green spaces in cities enhances the life quality of inhabitants:

Mental Health and Well-being: Green spaces are seen as essential for mental wellness. They help to calm, relax, and uplift mood, providing a sense of serenity and happiness. They also seem to slow people down, allowing them to breathe and be in the moment.

Community and Social Interaction: Green spaces are viewed as communal spaces where people can gather, take time off from their hectic daily life, and engage in activities like walking, exercising, and playing.

Physical Health: The importance of being outdoors and the role of green spaces in promoting physical health is highlighted.

Aesthetics and Atmosphere: Green spaces add joy to life and make urban landscapes less bland. They are seen as instant mood fixers.

Essentiality: The necessity of green spaces in urban areas is stressed. Their absence is seen as creating a vacuum.

Climate Change Awareness: Green spaces are seen as contributing to efforts in reducing climate change. They provide a better understanding and appreciation of nature, fostering more awareness of environmental issues.

Survey participants' perceptions of alterations in their stress levels or mindset when operating in an environment abundant with plants:

Positive Impact on Well-being: Many respondents reported a positive impact on their well-being when working in a plant-filled environment. They mentioned feeling more energized, calm, focused, and having a more positive attitude.

Reduced Stress Levels: A significant number of respondents reported reduced stress levels when surrounded by plants.

Sense of Responsibility: Some respondents mentioned feeling a sense of responsibility towards the plants, which in turn contributed to their overall well-being.

Lack of Exposure: A few respondents mentioned that they have not had the opportunity to work in a plant-filled environment or have not paid attention to the impact of such an environment.

Neutral or Unsure: Some respondents were unsure about the impact or stated that they did not notice any change in their stress levels or attitude.

Aesthetic Appreciation: Some respondents appreciated the aesthetic value of plants, mentioning that they enjoy seeing plants in their surroundings.

Survey participants' opinions on integrating plant-related activities, like gardening workshops or plant care sessions, into workplace wellness programs

Positive Attitude: Many respondents see plant-related activities as a positive addition to the workplace. They believe that interacting with nature can increase motivation and provide a much-needed break from work. Some respondents also mentioned the sense of accomplishment they feel when caring for plants.

Neutral Responses: Some respondents didn't express a strong opinion either way. They neither opposed nor supported the idea, indicating that they might be open to such initiatives but don't have strong feelings about them.

Concerns About Efficiency: A few respondents questioned whether plant-related activities would be a productive use of time. They seemed to be concerned that these activities might distract from work-related tasks.

Team Building and Bonding: Several respondents saw the potential for plant-related activities to strengthen relationships among colleagues. They believe that shared activities like gardening could foster a sense of community and teamwork.

Environmental Awareness: Some respondents appreciated the potential for plant-related activities to increase awareness and understanding of environmental issues. They see these activities as a way for organizations to contribute to society by promoting environmental stewardship.

Workplace Well-being: Respondents mentioned that these activities could contribute to a healthier work environment by reducing stress and promoting mental health. Some respondents also mentioned the aesthetic benefits of having plants in the workplace.

Compensation and Participation: One respondent suggested that participation in these activities should be optional and that employees should be compensated for their time if they choose to participate.

Creativity and Productivity: One respondent mentioned that these activities could boost creativity and productivity, suggesting that interacting with nature could stimulate new ideas and perspectives.

Sensitivity: One respondent mentioned that these activities could make people more sensitive, perhaps suggesting that caring for plants could foster empathy and compassion.
Output Boost: One respondent mentioned that these activities could be an effective way to boost output, although they did not elaborate on how this might be achieved.

Learning and Bonding: One respondent mentioned that these activities could be a great way to learn something new and bond with colleagues, suggesting that shared learning experiences could strengthen relationships.

Common themes and patterns Identified through the survey:

Green Spaces in Cities: The survey participants view green spaces as essential for enhancing the quality of life in cities. They contribute to mental well-being by providing a calming and relaxing environment that uplifts mood and slows down the pace of life. They also foster a connection to nature, which is seen as a basic human need. Green spaces are recognized for their environmental impact, particularly in improving air quality. They serve as communal spaces for social interaction and physical activities, adding aesthetic value to urban landscapes. The absence of green spaces is perceived as creating a vacuum in urban areas. Furthermore, they contribute to climate change awareness by fostering a better understanding and appreciation of nature.

Impact of Plants on Stress Levels and Mindset: Many respondents reported a positive impact on their well-being when working in a plant-filled environment, including feeling more energized, calm, and focused. A significant number of respondents reported reduced stress levels when surrounded by plants. Some respondents mentioned a sense of responsibility towards the plants, contributing to their overall well-being. However, a few respondents have not had the opportunity to work in such an environment or have not paid attention to its impact. Some were unsure about the impact or did not notice any change in their stress levels or attitude, while others appreciated the aesthetic value of plants.

Integration of Plant-Related Activities into Workplace Wellness Programs: Many respondents see plant-related activities as a positive addition to the workplace, believing that interacting with nature can increase motivation and provide a much-needed break from work. Some respondents also mentioned the sense of accomplishment they feel when caring for plants. However, a few respondents questioned whether these activities would be a productive use of time, expressing concerns about potential distractions from work-related tasks. Several respondents saw the potential for plant-related activities to strengthen relationships among colleagues, fostering a sense of community and teamwork. Some respondents appreciated the potential for plant-related activities to increase environmental awareness.

Environmental Stewardship and Awareness: Some respondents appreciated the potential for plant-related activities to increase awareness and understanding of environmental issues. They see these activities as a way for organizations to contribute to society by promoting environmental stewardship.

Workplace Well-being and Productivity: Respondents mentioned that these activities could contribute to a healthier work environment by reducing stress and promoting mental health. Some respondents also mentioned the aesthetic benefits of having plants in the workplace. One of the respondents mentioned that these activities could boost creativity and productivity,

suggesting that interacting with nature could stimulate new ideas and perspectives. One of the other respondents mentioned that these activities could be an effective way to boost output, although they did not elaborate on how this might be achieved.

Empathy and Team Building: A respondent mentioned that these activities could make people more sensitive, perhaps suggesting that caring for plants could foster empathy and compassion. Another respondent mentioned that these activities could be a great way to learn something new and bond with colleagues, suggesting that shared learning experiences could strengthen relationships.

Step - 5: Casual layered analysis of themes identified from survey

Litany

The observable phenomena reported in the survey are the positive impacts of green spaces and plants on mental well-being, social interaction, environmental awareness, and workplace productivity. For example, respondents reported feeling more energized, calm, and focused when working in a plant-filled environment. They also reported that on average, people have 1-3 plants and water them based on the plant's requirements.

Mental Well-being: The majority of people feel that the presence of plants enhances their mood and mental well-being. This is an observable phenomenon that aligns with the litany description of respondents feeling more energized, calm, and focused in a plant-filled environment.

Social Interaction: About 59.5% of people feel that having plants in co-working spaces would make them feel more connected to each other. This suggests that plants can foster social interaction.

Environmental Awareness: 78% of people have engaged in gardening activities, and 59% of people have engaged in conservation activities. This shows a high level of environmental awareness among the respondents.

Workplace Productivity: A majority of people (95.2%) believe that having plants in the workplace helps create a positive and productive environment. Additionally, 76.2% of people believe

that the presence of plants in the workspace can influence creativity and innovation.

Plant Care: On average, people have 1-3 plants and water them based on the plant's requirements. This shows that respondents are attentive to the needs of their plants, which aligns with the litany description.

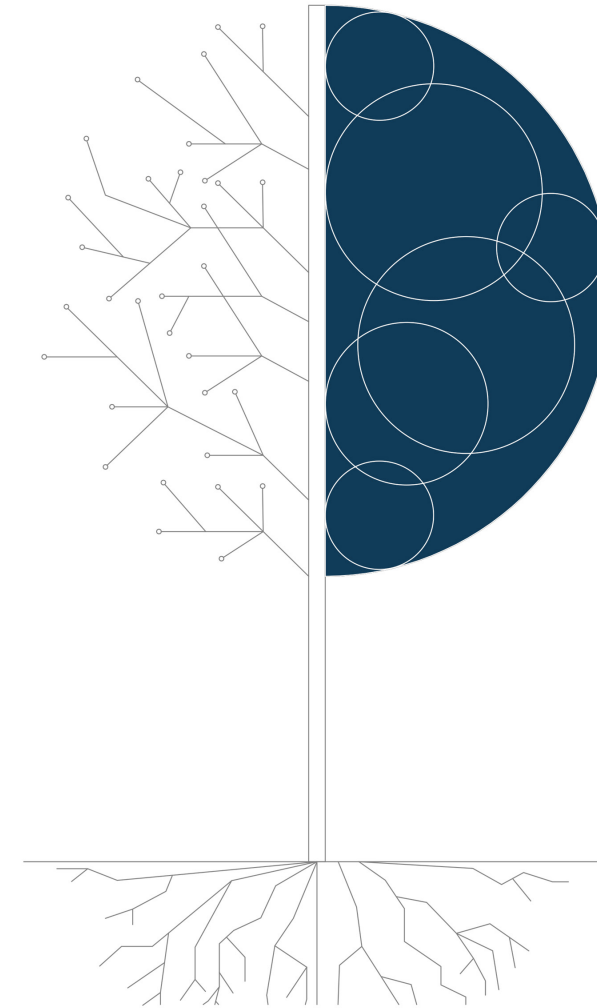


Figure 32: Litany based on survey

Social Causes (Systemic approach):

The social causes behind these phenomena include the urbanization process that often neglects the importance of green spaces, leading to a lack of connection with nature. In the workplace, the traditional focus on efficiency and productivity may overlook the potential benefits of integrating plant-related activities into wellness programs. For instance, 54.8% of respondents haven't worked in an environment where they got an opportunity to take care of plants as a group or community.

Urbanization and Green Spaces: The survey shows that 54.8% of people are surrounded by community or private gardens which connect them with nature. However, 35.7% feel that they are not as much connected to nature despite being surrounded by gardens. This reflects the social cause of urbanization, often neglecting the importance of green spaces, leading to a lack of connection with nature.

Workplace and Plant-Related Activities: The survey indicates that 95.2% of people believe that having plants in the workplace helps create a positive and productive environment. Yet, 54.8% of people haven't worked in an environment where they got an opportunity to take care of plants as a group or community. This suggests that traditional workplace focus on efficiency and productivity may overlook the potential benefits of integrating plant-related activities into wellness programs.

Education and Awareness: All people believe that it is important for schools and communities to include plant-related education and activities in order to raise awareness about issues. However, 54.8% of people aren't aware about the consequences of activities involving plants in their day to day life. This highlights the need for more education and awareness about the importance of plants and their impact on our lives.

Creativity and Innovation: Majority of the people (76.2%) believe that the presence of plants in the workspace can influence your creativity and innovation. This suggests that integrating plant-related activities in the workplace could potentially foster creativity and innovation.

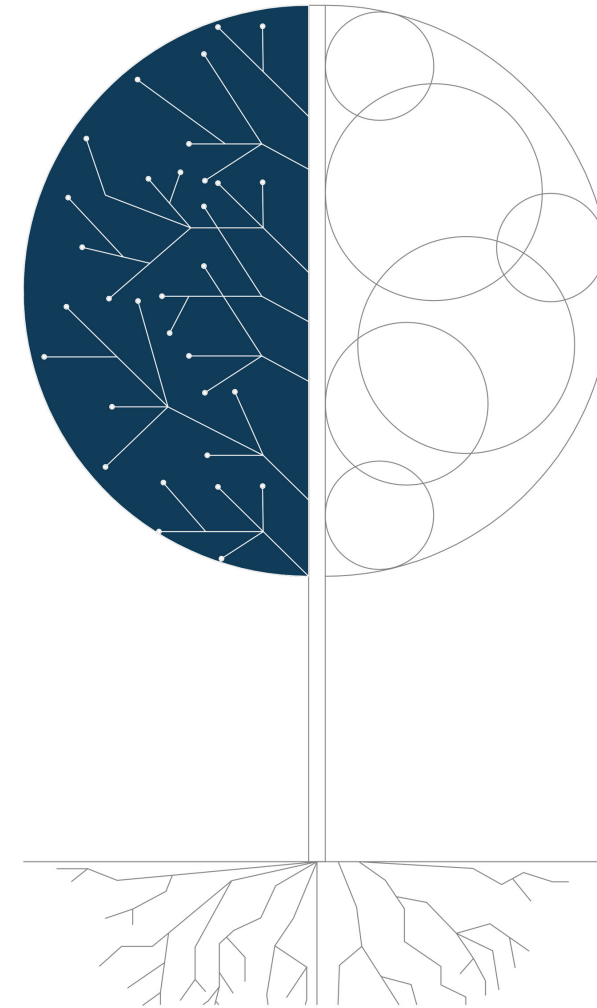


Figure 33: Social Causes based on survey

Worldview (Paradigms):

The worldview underpinning these social causes can be seen in the respondents' belief in the intrinsic value of nature and its positive impact on human well-being. This is reflected in their appreciation for green spaces and plants, and their belief in the potential benefits of integrating plant-related activities into workplace wellness programs. However, there are also differing views, with some respondents questioning the productivity of plant-related activities.

Intrinsic Value of Nature: The majority of people have plants in their home, and on average, people have 1-3 plants. This suggests a recognition of the intrinsic value of nature.

Positive Impact on Well-being: The majority of the people feel the presence of plants helps in enhancing their mood and mental well-being. This is a clear indication of the belief in the positive impact of nature on human well-being.

Questioning Productivity: While 76.2% of people believe that the presence of plants in the workspace can influence their creativity and innovation, 23.8% are not sure if the presence of plants in the workspace can influence their creativity and innovation. This indicates some respondents questioning the productivity of plant-related activities.

Differing Levels of Connection with Nature: While 54.8% of people are surrounded by community or private gardens which connect them with nature, 35.7% feel that they are not as much connected to nature despite being surrounded by gardens. 9.5% of people are staying in places where they don't have immediate access to green spaces. This shows varying degrees of connection with nature among the respondents.

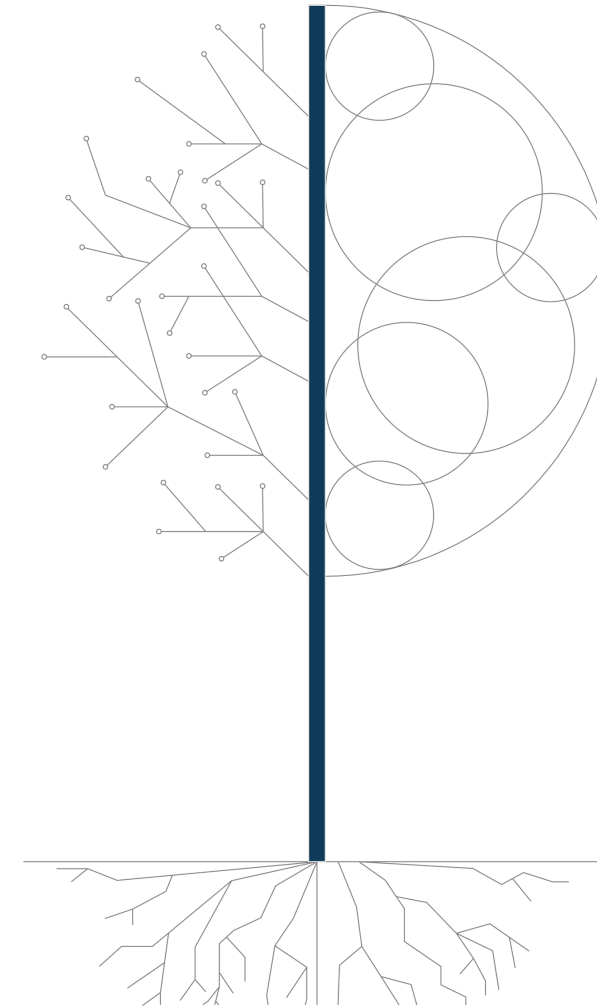


Figure 34: Worldview based on survey

Myth (metaphor) :

The deep story or myth influencing these worldviews could be the narrative of “Nature as Nurturer”. This narrative sees nature as a source of healing and well-being, fostering a sense of responsibility towards the environment. It suggests a shift from viewing nature as a resource to be exploited, towards seeing it as a partner in promoting human well-being and environmental sustainability.

Nature as a Source of Healing and Well-being: The majority of people feel that the presence of plants enhances their mood and mental well-being. This is further supported by the fact that 85.7% of people have tried using plant-based home remedies and products for improving their health or relaxation.

Responsibility Towards the Environment: 59% of people have engaged in conservation activities, and the majority think it’s important to protect habitats. This shows a sense of responsibility towards the environment.

Shift from Exploitation to Partnership: The fact that respondents water the plants based on the requirement of the plant, and that 78% of people have engaged in gardening activities, suggests a shift from viewing nature as a resource to be exploited, towards seeing it as a partner.

Promoting Human Well-being: Majority of the people (95.2%) believe that having plants in the workplace helps them to create a positive and productive environment. 76.2% of people believe that the presence of plants in the workspace can influence their creativity and innovation.

Environmental Sustainability: All people believe that it is important for schools and communities to include plant-related education and activities in order to raise awareness about issues. This suggests a commitment to environmental sustainability.

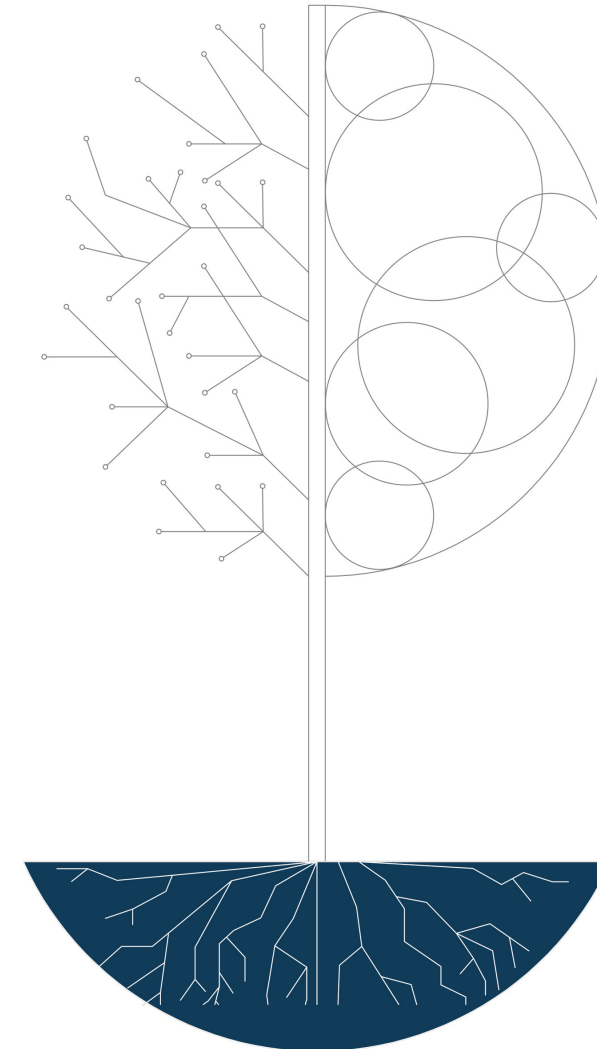


Figure 35: Myth/Metaphor based on survey

Takeaways from Causal Layered Analysis

According to the causal layered analysis, it can be inferred that the noticeable patterns in how people engage with plant-related activities are strongly influenced by underlying social factors and a changing perspective on the world.

The connection to nature, therapeutic benefits, educational opportunities, personal growth, shared engagement, and good influence on well-being, among other factors, are not merely isolated occurrences. These responses are related to wider social, economic, and political systems.

Systemic causes such as urbanization, increasing awareness of mental health, the pursuit of lifelong learning and personal growth, and changing family dynamics are driving these developments.

Furthermore, these underlying reasons are themselves expressions of a shifting perspective. This worldview encompasses a shift towards a broader understanding of health, a greater emphasis on environmental sustainability, and the importance of community and social involvement in a society that is becoming more digitized.

Engaging in plant-related activities involves an intricate combination of visible patterns, underlying causes, and changes in perspective. It mirrors our inherent need to establish a connection with the natural world, our reaction to societal and environmental shifts, and our developing comprehension of physical and mental wellness.

This analysis highlights the significance of taking into account these layers of causality when comprehending and dealing with the patterns associated with plant-related activities. Furthermore, it emphasizes the capacity of these activities to enhance individual and collective welfare, ecological durability, and the development of communities.

Relevance to the research questions

Tactile Interactions vs Remote Relationships: The analysis highlights the importance of a connection to nature and the therapeutic advantages of plant-related activities. This directly relates to the first research question about the physiological effects on plant growth and psychological impacts on human well-being. The systemic causes and worldview shifts identified suggest that tactile interactions with live plants could have different and potentially more profound impacts compared to technologically mediated remote relationships.

Emotional and Psychological Effects of Physical Touch: The conclusion underscores the positive impact on well-being, the sensory pleasure, and the care and nurturing associated with plant-related activities. These findings can provide valuable insights into the emotional and psychological effects of physical touch with plants on human well-being, especially in the context of increasing prevalence of remote interfaces that lead to disconnection from natural environments.

Physiological and Psychological Responses: The analysis reveals a complex interplay of observable trends, systemic causes, and worldview shifts in individuals' engagement with plant-related activities. This can help understand how specific physiological and psychological responses experienced by individuals when physically interacting with plants utilized as live display mediums compare to the experiences facilitated by remote interaction technology.

Horizon 1: Short-Term (1-2 years)

In this horizon, I have focused on the immediate and tangible impacts of integrating green spaces and plant-related activities in urban environments and workplaces. The initiatives under Horizon 1 are driven by the understanding that plants and green spaces significantly contribute to mental well-being, stress reduction, and fostering a positive environment.

The key areas of focus include urban planning initiatives that prioritize creating parks and community gardens, mental health campaigns that highlight the benefits of plants, workplace plant integration, educational programs on the psychological benefits of plants, and the integration of plant-related activities into workplace wellness programs.

Green Spaces in Cities:

Urban Planning Initiatives: With the majority of respondents having plants at home and valuing green spaces, urban development projects can prioritize creating parks and community gardens. This aligns with the 54.8% of people who feel connected to nature through such spaces.

Mental Health Campaigns: Since most participants feel that plants enhance mood and mental well-being, campaigns can highlight these benefits, encouraging city dwellers to support more green initiatives.

Impact of Plants on Stress Levels and Mindset:
Workplace Plant Integration: Given that 95.2% believe plants create a positive work environment,

companies can be encouraged to integrate indoor plants and living walls, potentially influencing the 54.8% who haven't had the chance to engage with plants in a group setting.

Educational Programs: With unanimous agreement on the importance of plant education, schools and workplaces can introduce modules on the psychological benefits of plants, catering to the 85.7% who have used plant-based remedies for health and relaxation.

Integration of Plant-Related Activities into Workplace Wellness Programs:

Pilot Wellness Programs: Organizations can pilot programs where employees engage in gardening, which could appeal to the 78% who already participate in such activities and the 76.2% who believe in the creative influence of plants.

Community and Co-working Spaces: For the 59.5% who feel that plants in co-working spaces foster connection, shared plant care activities can be introduced to enhance team bonding and address the 38.1% who are unsure of the impact.

In conclusion, Horizon 1 emphasizes the importance of integrating green spaces and plant-related activities into our daily lives, particularly in urban and workplace settings. The initiatives proposed not only aim to enhance the aesthetic appeal of these spaces but also to leverage the therapeutic benefits of plants for mental well-being and stress reduction. By piloting wellness

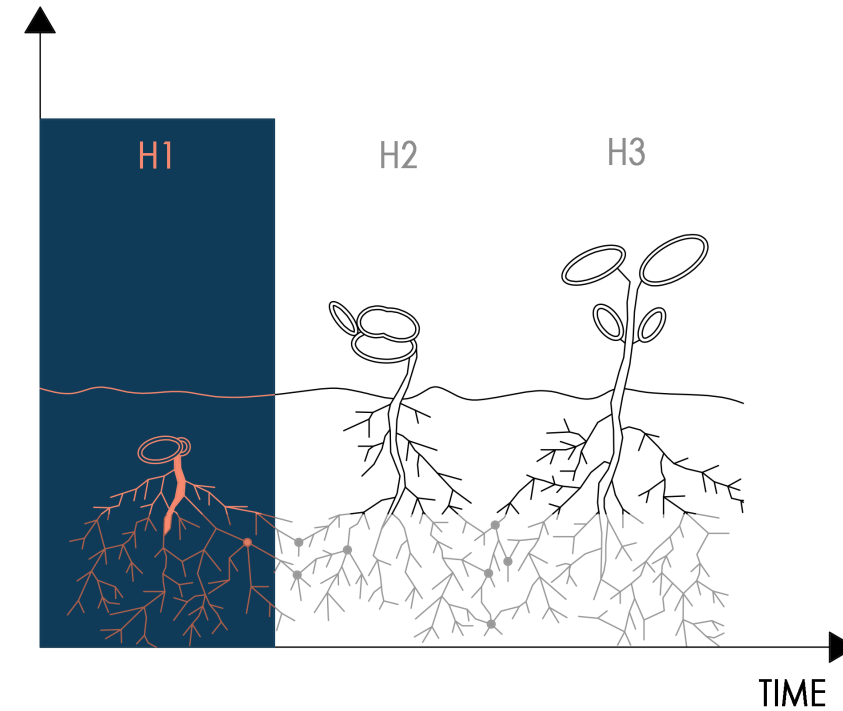


Figure 36: Horizon-1 based on survey

programs and introducing shared plant care activities, we can foster a sense of community and connection, thereby creating more harmonious and productive environments. The unanimous agreement on the importance of plant education

further underscores the need for continued efforts in this direction. As we move forward, these initiatives will play a crucial role in shaping our cities and workplaces, making them healthier, greener, and more sustainable.

Horizon 2:

Horizon 2 focuses on Emerging Trends that are currently developing and have the potential to become more significant in the future. Based on the survey responses, we can delve deeper into the trends of Environmental Stewardship and Awareness, Workplace Well-being and Productivity, and Empathy and Team Building.

Environmental Stewardship and Awareness: The survey indicates that a majority of people recognize the importance of plants in enhancing mood and mental well-being, with 85.7% trying plant-based remedies for health or relaxation. This suggests a growing trend towards natural solutions and an increased awareness of environmental health. Additionally, 59% have engaged in conservation activities, and there is a strong belief in the importance of protecting habitats. This could be expanded to include community-led conservation projects and educational programs that focus on sustainable practices and the importance of biodiversity.

Workplace Well-being and Productivity: With 95.2% believing that plants create a positive and productive environment, there's a clear trend towards biophilic design in workplaces. The aesthetic benefits of plants, along with their ability to reduce stress, can be further explored through the introduction of green spaces in office areas, living walls, and employee-led gardening clubs.

These initiatives not only enhance the work environment but also contribute to team building and a sense of community within the workplace. **Empathy and Team Building:** The survey shows that while 54.8% haven't had the opportunity to care for plants as a group, there is a desire for more community involvement in plant care. This opens up avenues for team-building activities such as group gardening projects or 'adopt a plant' programs that encourage collective responsibility and foster empathy among colleagues. Moreover, 59.5% feel that plants in co-working spaces would enhance connectivity, suggesting that shared plant care could be a valuable addition to collaborative work environments.

In conclusion, Horizon 2 presents a promising future where environmental stewardship becomes a part of our lifestyle, workplaces transform into green havens enhancing productivity, and empathy and team building are fostered through shared responsibilities in plant care. The survey results suggest a shift towards a more sustainable and connected world, where plants play a pivotal role in enhancing our well-being and fostering a sense of community. As we move forward, these insights could guide the development of community-led conservation projects, biophilic workplace designs, and team-building activities centered around plant care, thereby creating a healthier and more empathetic society.

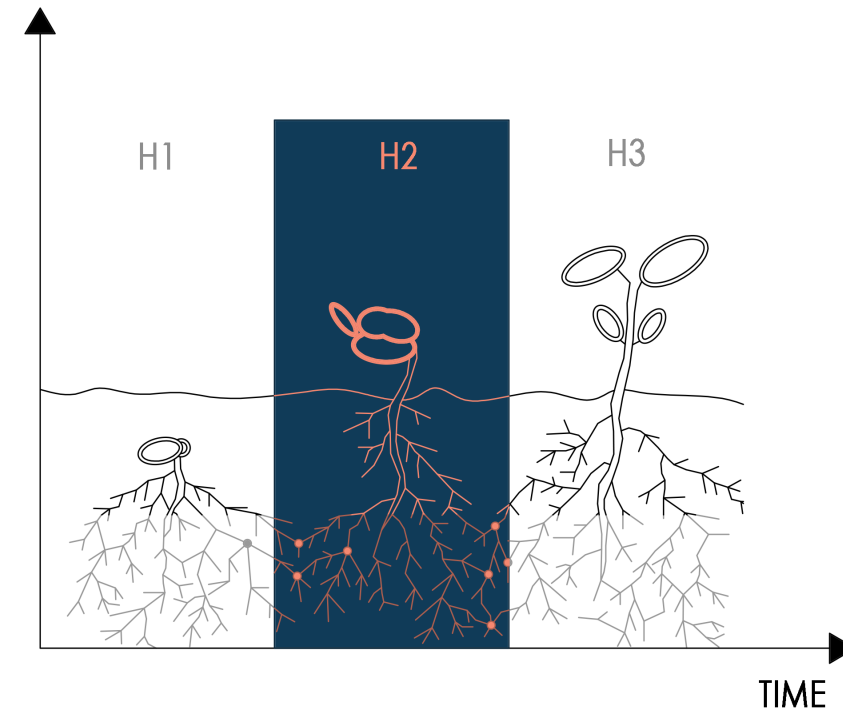


Figure 37: Horizon-2 based on survey

Horizon 3:

Horizon 3, as part of the Horizon Scanning process, delves into the significant potential of incorporating plant-related activities into our everyday routines, with a particular emphasis on the workplace environment. The survey findings reveal a substantial personal value attributed to plant interaction, with a majority of individuals already participating in plant-related activities at home and in gardening endeavors. This existing engagement provides a unique opportunity to harness this interest towards the creation of more sustainable, productive, and wellness-oriented environments.

Compensation and Participation: The survey indicates that a majority of people already engage with plants at home and in gardening activities, suggesting a pre-existing personal value placed on plant interaction. To advocate for policies that recognize and compensate for participation in plant-related activities, one could propose incentive programs within workplaces that reward employees for their involvement in maintaining office green spaces or participating in community gardening. This could be in the form of extra vacation days, wellness credits, or even financial bonuses.

Expansion and Advocacy: With 59% of respondents engaged in conservation activities and a strong belief in the importance of protecting habitats, there's a clear mandate for expanding green spaces.

Advocacy efforts could focus on urban planning policies that mandate a certain percentage of green space in new developments.

Additionally, partnerships with local governments and businesses could be formed to create 'green corridors' in cities, connecting existing parks and natural areas.

Integration of Plant-Related Activities into Workplace Wellness Programs: Given that 95.2% of respondents believe plants create a positive and productive environment, integrating plant-related activities into workplace wellness programs could include 'green breaks' where employees engage in short, guided interactions with plants to refresh their minds. Workshops on plant care and horticulture could also be offered as team-building exercises, fostering a sense of community as indicated by the survey.

Workplace Well-being and Productivity: To capitalize on the belief that plants can boost creativity and innovation (76.2% of respondents), workplaces could design 'innovation gardens' where employees can brainstorm and collaborate surrounded by greenery. The presence of plants could be used to stimulate new ideas and perspectives, potentially leading to breakthroughs in various fields.

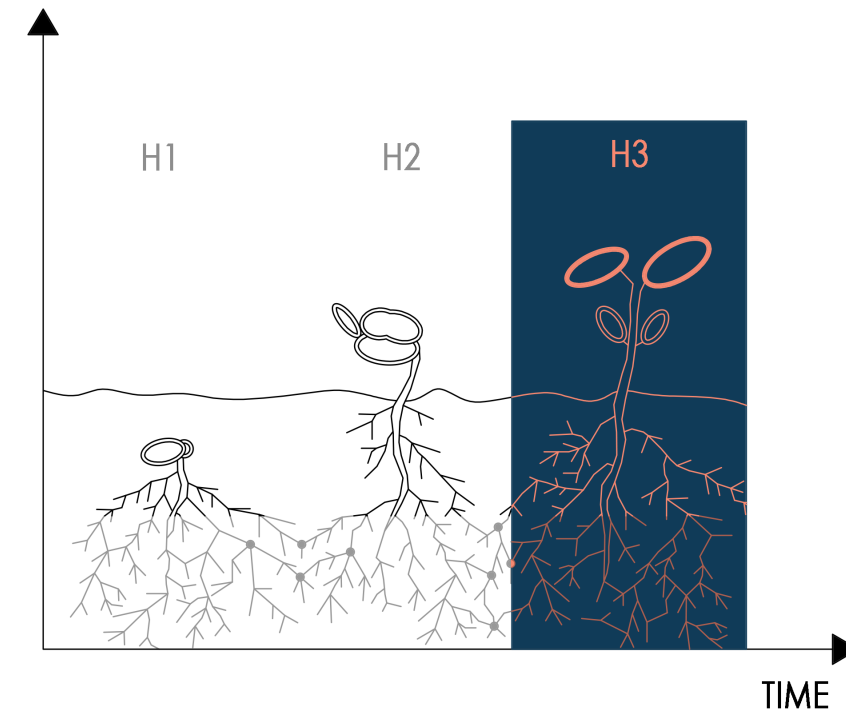


Figure 38: Horizon-3 based on survey

Takeaways from Horizon Scanning:

Engaging with plants, whether through indoor cultivation or outdoor gardening, has numerous advantages that encompass personal, societal, and environmental aspects. From an individual standpoint, it offers therapeutic advantages, chances for learning, and sensory enjoyment. Additionally, it cultivates a profound emotional connection with the natural world, fostering empathy and gaining fulfillment from the growth of plants. Green spaces on a societal level promote community engagement and boost visual attractiveness. Gardening enhances air quality, contributes to climate change mitigation, and fosters biodiversity, all from an environmental perspective. Plant maintenance fosters stewardship and instills a sense of duty. Botanical maintenance is more than simply a hobby; it is a comprehensive method that connects human well-being with environmental sustainability. It is evidence of the significant influence of nature on our lives and our mutual responsibility to protect and promote its well-being.

Relevance to the research questions

It highlights the therapeutic advantages, sensory enjoyment, and emotional connections that arise from engaging in direct, tactile encounters with plants. These advantages have the potential to positively influence both the growth of plants and the well-being of humans. Conversely, remote interactions facilitated by technology may lack the same degree of sensory involvement and emotional attachment, which could result in distinct physiological and psychological consequences. Emphasizes the emotional and psychological benefits of physical touch, specifically in relation to witnessing plant growth. It suggests that the joy and satisfaction experienced may be a direct outcome of interacting with plants through physical contact. Additionally, it discusses the establishment of an emotional connection with plants, exemplifying empathy and nurturing development. These elements would be greatly affected by the growing popularity of distant interfaces, resulting in a detachment from natural ecosystems.

Highlights the diverse advantages of interacting with plants, which are likely to be more strongly felt during direct physical touch compared to remote interaction. The sensory gratification, curative advantages, and emotional connections established through direct engagement with plants may vary from those aided by distant contact technologies.

Step- 7: Integrated Model

In the realm of organizational research, the metaphorical landscape of trees provides a powerful lens through which to explore the intricacies of systems, change, and growth. In this paper, we introduce the concept of dual trees—the Tree of Literature and the Tree of Surveys—as representations of causal layered analysis (CLA). These trees serve as visual frameworks for understanding the layers of insight within an existing system. We delve into their symbolism, drawing parallels between their components and the layers of CLA. Additionally, we explore the critical role of horizon scanning—the fertile ground between the trees—in bridging tradition and innovation.

The Tree of Literature: Roots in Tradition

On the left stands the venerable Tree of Literature. Its crown, adorned with leaves of scholarly wisdom, rustles with the litany—the surface-level facts, data, and insights drawn from existing research. These leaves sway in the winds of academic discourse, ever responsive to the changing environment. But it is the branches that provide stability—the systems layer. These branches, shaped by established theories and paradigms, hold the weight of accumulated knowledge. The bark, etched with epistemological patterns, encases the trunk—the worldview layer. Here, beliefs, cultures, and values form the foundation, shaping how we interpret reality. Deep within the soil, the roots delve into collective memory—the myth and metaphor layer. These roots draw sustenance from ancient debates,

seminal works, and unconscious narratives. The Tree of Literature stands as a testament to tradition, its mycelium network connecting it to scholarly conversations across time.

The Space Between: Horizon Scanning

Between the twin trees lies a fertile expanse—the land of scope and potential growth. This is the realm of horizon scanning, akin to the mycelium network in a jungle. It connects the roots of both trees, bridging tradition and innovation. Just as mycelium nourishes neighboring plants, horizon scanning feeds emerging insights. It reminds us that growth is not linear; it requires balance—a dynamic equilibrium between existing systems and new possibilities.

The Tree of Surveys: Branches Reaching Out

On the right stands the Tree of Surveys, bathed in empirical sunlight. Its crown bears leaves of freshly collected data—the litany echoing through questionnaires and interviews. These leaves quiver with immediacy, reflecting the pulse of the present. The branches mirror those of the Tree of Literature, but they are shaped by empirical evidence—the systemic layer informed by real-world contexts. The bark, textured by diversity, captures lived experiences—the worldview layer seen through an empirical lens. And beneath the surface, the roots intertwine with the mycelium network, drawing inspiration from the Tree of Literature while reaching toward emerging horizons.

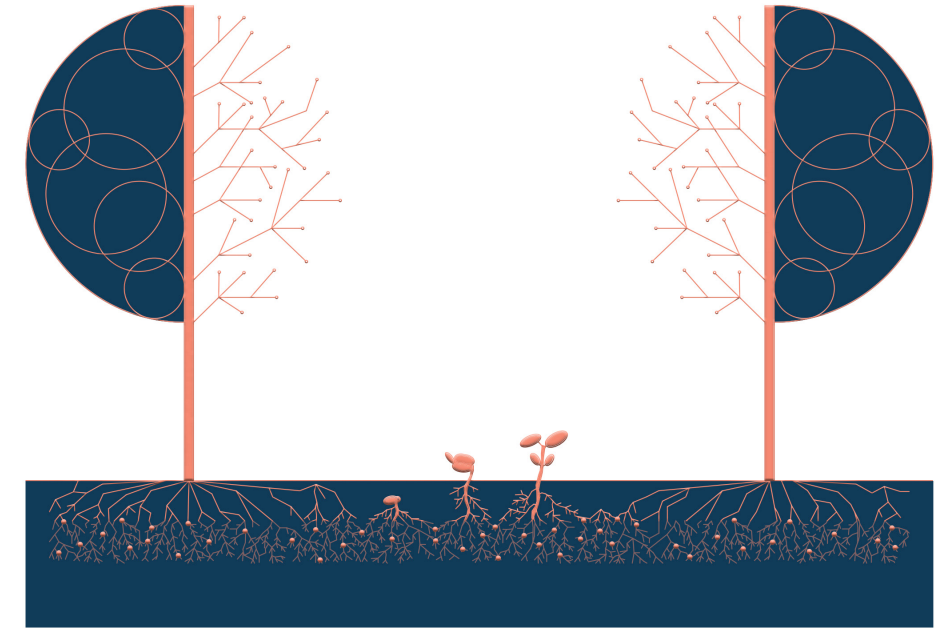


Figure 39: Integrated model

Conclusion: Dynamic Stability and Resilience

In this forest of research, the twin trees stand as a harmonious duality. They remind us that growth is not disruptive; it is a dance—a symphony of leaves, branches, bark, and roots. Just as nature balances stability and resilience, so must organizations. By embracing both tradition and innovation, we approach growth as dynamic stability.

By embracing both tradition and innovation, we approach growth as dynamic stability. We nurture existing systems while exploring new frontiers. The interconnectedness of these trees—their mycelium bridge—guides us toward a holistic understanding of organizational dynamics.

CONCLUSION

The comprehensive context mapping exercise has provided a deep understanding of the system and its environment, highlighting the trajectory of interaction design and technology towards a future that is more sustainable, socially interconnected, and harmonious with nature. This transition is supported by enduring patterns that suggest a growing consciousness of environmental sustainability, social interconnectedness, mental and physical well-being, advancements in education, and the convergence of digital and natural realms.

The findings from this study underscore the importance of maintaining a genuine connection with nature, despite our technological progress. It suggests that while remote technology can offer benefits, it is crucial to consider the physiological effects on plant growth and the psychological impacts on human well-being to maintain equilibrium.

The emotional and psychological effects of physical contact with plants on human welfare are highlighted in the findings. This underscores the importance of cultural activities that encourage direct interaction with nature and illuminates the potential of HCI systems to leverage plant stimuli for interactive experiences. For instance, HCI systems could be designed to utilize plant stimuli in educational settings, enhancing learning experiences by integrating nature into the curriculum. Similarly, in the workplace, such systems could promote mental health by providing

a calming, natural element to the environment.

The conclusions analyze the potential benefits and challenges of incorporating plants into HCI designs. It suggests that while there are potential benefits such as improved user experience and environmental sustainability, there are also significant challenges such as the risk of becoming disconnected from the natural environment and the oversimplification of complex ecosystems. This study examines the physiological and psychological responses of individuals when physically interacting with real plants used as display mediums, compared to experiences facilitated by remote interaction technologies.

Institutional rules and ethical principles play a crucial role in achieving a harmonious balance between the benefits of remote technology and the necessity of preserving a genuine connection with nature. Similarly, providing economic incentives for sustainability and balanced development plays a key role in promoting long-term investment in sustainable technologies.

Future research could explore what these incentives might look like and how they could be effectively implemented. This could involve conducting economic analyses to determine the costs and benefits of different incentives, or working with businesses and governments to pilot incentive programs.

Engaging in cultural activities that directly involve nature and promote the creative use of technology and natural materials is crucial for appreciating the complex nature of ecosystems and ethical implications, and harnessing our inherent cultural connection to the natural world. The models proposed in this study, such as the Tree of Literature and the Tree of Surveys, serve as visual frameworks for understanding the layers of insight within an existing system and could be used to explore the intricacies of systems, change, and growth. Future work could focus on refining these models, incorporating additional variables, and testing them in different contexts.

Practically, it is recommended to develop HCI systems that utilize plant stimuli for interactive experiences and designs that promote shared responsibility for plant maintenance. A potential next step would be to design and prototype these experiences. This could involve developing interfaces that respond to plant stimuli in real-time, creating immersive environments that blend the digital and natural realms, or exploring novel ways of using plants as input devices. However, it is essential to approach these issues with caution, seeking a balanced and harmonious state between human needs and the recognition of nature's complex and intrinsic value.

Ultimately, achieving the seamless integration of plants into HCI designs requires a careful balance between human needs and the intrinsic value and complexity of the natural environment.

.This balance encompasses not only efficiency and convenience but also the acknowledgment of the intricate interdependencies within ecosystems and the ethical implications they entail. As we move towards a future characterized by greater integration of technology and nature, it is crucial that we approach this development with deep respect for the environment and a steadfast commitment to sustainability.

FUTURE DIRECTIONS

Further Development of HCI Models: The new models created in this study provide a foundation for further research. Future work could focus on refining these models, incorporating additional variables, and testing them in different contexts.

Prototyping Interaction Experiences: The study has highlighted the potential of plant stimuli in creating interactive experiences. A potential next step would be to design and prototype these experiences. This could involve developing interfaces that respond to plant stimuli in real-time, creating immersive environments that blend the digital and natural realms, or exploring novel ways of using plants as input devices.

Economic Incentives for Sustainability: Providing economic incentives for sustainability and balanced development plays a crucial role in encouraging long-term investment in sustainable technologies. Future research could explore what these incentives might look like and how they could be effectively implemented. This could involve conducting economic analyses to determine the costs and benefits of different incentives, or working with businesses and governments to pilot incentive programs.

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APPENDICES

Survey Questions:

- Do you keep any plants in your home?
- How many plants do you currently have?
- What kinds of plants do you have?
- How frequently do you water your plants?
- Do you feel that having plants enhances your mood and mental well being?
- Have you ever engaged in gardening or growing plants ?
- If yes, what do you enjoy most about gardening or taking care of plants?
- Do you believe that spending time in surroundings or green spaces has an impact on your overall health?
- Have you ever taken part in tree planting or conservation activities?
- On a scale of 1 to 5, with 1 being not important and 5 being very important, how significant do you think it is to protect habitats and biodiversity?
- Are there any places like parks or botanical gardens nearby that hold a connection with nature for you?
- Have you ever tried using plant based products, such as remedies or essential oils for the purpose of improving your health or finding relaxation?
- In your opinion how do you believe the presence of green spaces in urban areas impacts the overall quality of life for residents?
- Have you ever taken into consideration the consequences of your activities involving plants like where they're sourced from or how they are disposed of?
- Do you think it is important for schools and communities to include plant related education and activities in order to raise awareness about issues?
- On a scale from 1 to 5 with 1 representing least connected and 5 representing most connected, how would you rate your overall relationship with plants?
- Do you believe that having plants in the workplace helps to create a more positive and productive environment?
- Have you observed any changes in your stress levels or attitude when working in a plant-filled environment?
- Have you ever worked in a place where there was a group effort to care for plants?
- How do you feel about the incorporation of plant-related activities into workplace wellness initiatives, such as gardening courses or plant care sessions?
- Can the presence of plants at the workplace, in your opinion, influence creativity and innovation?
- Do you think that having plants in shared workspaces might help colleagues feel more connected?