FUTURE OF DWELLING: INDOOR PLANTS AND PRODUCE

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ABSTRACT

Our agricultural system has a gigantic task ahead, by 2050 it will need to increase food production by about 70% in order to meet the needs of a global population of 9.7 billion people, 68% of whom are projected to live in urban areas. Presently, 38% of the planet's unfrozen land is used for growing food, using 70% of our water consumption. The agricultural system needs to become more efficient starting by using new technologies to increases productivity. Indoor farming has the potential to present solutions that can help mitigate this problem at both the urban and single dwelling levels. The future of food production starts at home by bringing plants indoors. Interest in greenifying our interiors is not new. As humanity moved from nomadic hunter-gatherers (in the Neolithic) to becoming urban dwellers, plant domestication was one of the main factors behind their settling down. Across cultures all over the world and for generations, humans have brought plants into their homes. Before we called them houseplants, scented and flowering plants were taken indoors so that their fragrance and blooms could be enjoyed, while also masking unwanted smells inside the house. Well known as stress busters, mood enhancers and incorrectly as air purifiers, it's easy to see why houseplants are having a revival. The present trend has been attributed to eco-friendly, health-conscious millennials who want to bring the great outdoors into their inner-city apartments and nurture something alive in an increasingly virtual world, but it could go further than that. What if indoor houseplants could also feed us? The future of dwelling relies on making home grown produce an inherent aspect of the interior environment, using smart gardening, self-watering garden systems, hydroponic kitchen appliances and other emerging technologies to do so. This paper will focus on the future of indoor plants and their sustainable potential in helping mitigate the climate crisis, as they are integrated in an interior environment to help define the future of dwelling.

Keywords: indoor farming, greenifying, plants, hydroponics, sustainable potential.

1 INTRODUCTION

Humans and plants have shared a coevolution that has been central to our well-being. Plants are not only an important source of food and medicine but also inherently present in our culture, legends, folklore, and religions. Their domestication for agriculture presented a major change in human history, allowing society to develop while our settlements increased in complexity and size. Today, modern urban centres rely on the stable and reliable production and distribution of plant-based food to subsist. In globalized society this means produce needs to travel from far away to make it to our plate. This food carries with it a huge carbon footprint (food miles) that takes away any benefits it might have gained through sustainable farming techniques. To counter this problem, the local food movement, with the goal of consuming food produced and grown in its nearby geographical area, has been gaining traction as a way of eating fresh and nutritional foods while reducing one's environmental impact and cutting food cost. Agricultural areas around cities are being complemented by urban farms, in rooftops, residual empty lots, community gardens and vertical hydroponic farms. This last one, with the potential to bring farming indoors into the house, allowing it to produce a percentage of its tenant's plant intake. Indoor plants contribute to our mental well-being but what if they could also be set to provide nourishment. As we look into the future of dwelling, houses will need to give back by recycling and producing water, creating energy from the sun or wind, deal with waste management through

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composting and produce a percentage of their own food. Hydroponics have already started to make their presence known in kitchen appliances, facilitating the agricultural process by making it home friendly. The domestication of plants has arrived indoors in a sustainable, adaptable, and efficient way. Ahead, we will look into the history of the human–plant relationship, their benefits as we bring plants indoor and the future of our relationship to plants in the home. Our motivation may have changed, but it seems that having greenery and flowers in our homes is just as important for us today as it ever was.

2 THE CHALLENGES OF FUTURE-PROOFING OUR FOOD SUPPLY

Humanity is now up against multiple demanding issues that are forcing dramatic change to our global lifestyles: climate change, infectious diseases, increasing urbanization, and the depletion of our natural resources. All of them adding uncertainty to our capacity to feed the planet's inhabitants. With a global population expected to reach 9.7 billion people by 2050 [1], it is expected that food production will need to increase by 60% to 70% [2]. To achieve this under our present system would require 593 million additional hectares of agricultural land. If this amount of land was actually used for this purpose, the climatic implications would be catastrophic. A sustainable plan would have to find solutions that function withing the agricultural land already in use. Taking into account that the population growth will not be evenly balanced around the world. According to the United Nations, India, Nigeria, Pakistan, the Democratic Republic of the Congo, Ethiopia, Tanzania, Indonesia, Egypt, and the United States will be responsible for half of the population growth. Placing economic pressure on their poorest citizens and with that their access to food. But we have to understand that producing the amount of food needed does not guarantee that it will be distributed equitably ending global hunger. Because the vast majority of the population growth by 2050 will take place in urban areas, urban solutions are needed. While the governments of the world will attack the food shortage in multiple ways, incorporating indoor farming at the macro and micro levels in the urban centres can help mitigate this issue.

3 A BRIEF HISTORY OF HUMANS AND PLANTS

It's believed that humans first started domesticating plants (figs) between 11,400 and 11,200 years ago, in an early neolithic town called Gilgal in present day Jordan [3]. Preceding the domestication of cereal by about a thousand years. Around 11,000 years ago humans went from exploiting the earth to actively changing their environment to suit their needs. By intervening in nature, humanity decided to supply their own food, shifting from a nomadic to a sedentary life. And since then, through a process of trial and error, humanity has domesticated plants for their specific function, leading to the development of their civilization. This symbiotic relationship between human and plant eventually brought the plant to be part of the urban landscape. Tales of emperor Nebuchadnezzar (between 605 and 652 BCE) creating the hanging gardens of Babylon to please queen Amytis tells us a lot about plants and the urban realm [4]. To bring plants inside, some cultures have traditions of dwarfing trees for decorative purposes through a process of domestication called Hon-Non-Bo (in Vietnam), Penjing (in China) and Bonsai (in Japan) [5]. As early as 1,000 BCE, plants were used indoors for ornamental purposes in China. Since this was a resource-intensive practice of plant domestication that was not intended for consumption, houseplants were primarily a status symbol. Indoor plants were slower to reach Europe. While many civilizations potted plants, the first indoor plants can be traced back to the Egyptians, Greeks and Romans around 400 BC [6]. Romans used flowers (specially the rose) to beautify the street, eventually bringing them into their villas and bathhouses. During the Renaissance (15th and 16th centuries), sailors started bringing back botanical samples back home starting

a fashion for orangeries and pleasure gardens. Some of these imported plants were not equipped to survive the shift in seasonal weather, so cultivating them entailed a reliance upon heated glasshouses and dedicated gardening staff making of them indoor plants. The first botanical gardens were stablished in the 16th century in Florence (1545), Padova (1545) and Pisa (1544) in Italy. Followed by the Hortus Botanicus Leiden (Netherlands) in 1590, the Botanical Garden of the University of Valencia (Spain) in 1567, Leipzig Botanical Garden (Germany) in 1580, the Botanischer Garten Jena (Germany) in 1586, the Jardin des Plantes de Montpellier (France) in 1593, and the University of Copenhagen Botanical Garden (Denmark) in 1600. Colonialism brough the first botanical garden to India in 1787. In Europe in the 17th century, citrus trees had become a status symbol and with them the green houses needed to let them survive the winter [7]. In 1652, Sir Hugh Platt wrote a popular book called *The Garden of Eden* about indoor plants and gardening popularizing the subject [8]. And after that, greenhouses started popping out all over England. Potted plants became a necessity to bring back to England plants from the colonies. With industrialization during the Victorian era (1837–1901), ordinary homes were beginning to resemble more closely the western homes we know today. Indoor plants had, for the first time, taken root in middle class homes. By then, heated homes allowed for the growth of exotic tropical and subtropical plants. Larger houses were designed with solariums, parlours, conservatories, and green houses where indoor plants became an important part of the décor. Archetypal elements of Victorian architecture like bay windows and sun porches have its origins from the desire for indoors greenery. Plants were inexpensive, brought the outdoors in and could turn any room into a tropical haven. Some of the more popular types of house plants at the time were: The cast iron plant (Aspidistra Elatior), the Boston Fern (Nephrolepis Exaltata), the Kentia Palm (Howea Forsteriana), the Majesty Palm (Ravenea Rivularis), the Jasmine (Jasminum), all of them hardy tropical plants. By the middle of the 19th century gardening books and magazines had indoor plants playing an increasingly important role in interior design. Josiah Wedgwood founded his pottery company in 1759 (England) with an industrialized manufacturing process that catered both to high and low-end clients [9]. During the Art Nouveau period (1890–1910) natured inspired art in all its forms, its asymmetry, variety of textures, subtle colours, and smooth and wavy lines. Artistic motifs were drawn from the richness of native flora and fauna. Art Nouveau's interest in nature, which began at the end of the 19th century, continued into the 20th century until the arrival of modernism. The start of the 20th century saw a shift in attitudes about indoor plants. After the first world war, the minimalistic nature of modernism associated plants with an old-fashioned mentality. The tropical plants made way to more architectural plants like succulents and cacti. Between the 1920s and 1930s modernist architecture working on the interior–exterior spatial connection focused on the architecture–nature relationship. This was specially the case in Scandinavian design, Villa Mairea being a good example, designed by Alvar Aalto in Finland in 1937. Arne Wahl Iversen created furniture pieces that incorporated planters, clearly defining a role for greenery in the interiors they envisioned. Since then, potted plants have been an inherent element in interior design. The internet gave everybody the gardening know-how while technology has made plants cheaper and accessible. With increasing apprehension about climate change and awareness of the wastefulness of consumerism we have experienced a cultural shift towards embracing the natural. Today, seven out of every ten millennials consider themselves a plant parent, meaning someone caring for house plants [10]. Health and wellness are important to the millennial and post millennial generations, plants make healthier spaces by purifying the air, boosting our mood, and lowering our stress. For a generation dependent on social media, sharing platforms like Instagram and YouTube [11] have added a touch of fashion.

Encouraging self-care and nurturing, while creating a community around plants in a world where there is often a disconnect.

4 CAN PLANTS CLEAN THE AIR OF OUR DWELLINGS?

From the building materials to its furniture to all the household products in it, building occupants are constantly exposed to volatile organic compounds (VOC). The accumulation of these chemicals in badly vented spaces are causing indoor air quality problems that contribute to sick building syndrome (SBS) symptoms and other health problems. To reduce VOC from the air, architecture has traditionally used ventilation systems to bring fresh exterior air into the building displacing the stale air from the interior. The more a building ventilates the less SBS incidences. As we rely more on mechanical systems, cost and maintenance make us look towards alternative options to complement them. If indoor air quality is a problem, maybe plants can solve it since that is what they do by being natural filters. A study by NASA [12] found that indoor plants can scrub the air from carcinogens volatile organic compounds. While looking for ways to detoxify interior environments in the international space station, they found that certain plants could remove formaldehyde and benzene from the air. And while this is true in small, sealed chambers over long periods of time, it is not the case on the less controlled conditions of a house. An apartment is constantly exchanging air with the outside, this alone would not give plants enough time to filter chemicals out of the air. Air exchange with the exterior has a greater effect on indoor air quality than plants would. The plants in your home don't get the optimal conditions they would in a lab to maximize photosynthesis improving the plant's toxin-degrading abilities. Indoor plants do not function at a 100% of their ability. So, the answer is that plants can clean the air but in ways that are consequential for indoor inhabitation. This does not mean that indoor plants don't have other benefits, but at this time, it does not look like plants sitting passively in a house are effective enough in purifying indoor air quality [13]. Researchers suggest that you'd have to shelter a large number of plants to equal the air purifying efficiency of modern biofilters and other technologies. So, while air purifying is not really an advantage of having indoor plants, they do benefit our well-being in other ways.

5 SO, THEN WHAT ARE THE BENEFITS OF HAVING PLANTS AT HOME?

While the idea of indoor plants serving as an air purifier for dwellings is a myth, this does not mean that plants don't have other benefits worth considering. Spending time outside in nature has proven to improve our wellbeing [14] by reducing mental fatigue, helping us relax and improve cognition [15]. Although indoor plants are not a substitute for the great outdoors, immersing in nature may not always be feasible or practical. If interacting with plants outside has positive psychological results, these benefits should also manifest indoors. A study about the subject [16] suggests that active interaction with indoor plants can reduce physiological and psychological stress. In a way, plants can make us happy by beautifying our environment. Plants will add colour and liveliness to a space while also serving as noise reduction devices, screens, and dividers. There are also productivity results associated with this sense of calmness were plants in your environments affect your attention [17]. Work performance increases, our work becomes more accurate and of a higher quality when plants are around. And medically, plants in your bedroom or hospital room help you recover faster from illness, injury, or surgery [18]. Caring for a plant can play a role in a person's recovery and provide a sense of accomplishment as you see it grow. There is also a therapeutic side to working with plants where horticultural therapy can be used to increase a feeling of well-being in patients experiencing depression, anxiety, dementia, and other debilitating conditions [19].

Anecdotal and quantitative evidence suggest that humans are innately attracted to nature. In his book *Biophilia* (1984), Edward O. Wilson proposes a reason for our coevolutionary relationship to plants. He proposes that the tendency of humans to focus on, and to associate with nature, this tendency to seek connection with other life forms, has in part a genetic basis deeply rooted in our biology [20]. This hypothesis becomes important in urban environments, where we interact more with technology than nature. Specially after the quarantine of the pandemic where our interaction with other humans diminished. For some, plants substituted our biophilic connection. "The reasons why plants have these psychological benefits for us are still mostly unknown and may go back far in time, bound up in our unconscious awareness that without them, life for our species wouldn't be possible. The calm that pervades us in their presence may be the echo of an ancestral awareness that everything we need and every chance for our survival dwells in the green world. Now as long ago" [21]. And while indoor plants are beneficial to our mental health, they can also help mitigate the food shortages humanity will experience as the population of the planet increases. Urban farming can become an aspect of residential design.

6 HYDROPONICS AND INDOOR URBAN FARMING

Hydroponic agriculture is a relatively new technology that has grown in popularity by providing a faster plant growth rate and a higher yield, while requires less space, no soil, and being water efficient. Hydroponics were invented by William Frederick Gericke (1882–1970) in 1929 at the University of California in Berkeley. The technology was designed to grow plants using a water culture that supplied plants with all the minerals and nutrients that they would otherwise get from soil [22]. He realized that plants could be grown closer together than in soil. And that by adding nutrients and water as the plant grew, he was also able to make them live longer. Modern hydroponics have some advantages over traditional farming, the first is water conservation. Hydroponics use less water because it is recirculated. Only a small fraction of the water gets used by the plant recycling the rest of the water back into the reservoir. As this happens, the water gets constantly oxygenated, optimizing the roots oxygen intake. The process gives the farmer a huge amount of control over his environment by elimination soil-borne pests and diseases and the time it takes to deal with these problems. Today, hydroponic systems are automated and stackable allowing for a vertical far to be much more productive than traditional farming. And by being done locally, removing the long-distance transportation cost from the equation. The system is being used presently in the international space station with plans to be adapted for production on the Moon and Mars [23]. Back on earth these technologies are already being sold off the shelf.

7 GROWING PRODUCE INDOORS AT HOME

So, why have hydroponics farming taken so long in arriving to our homes? The answer is that while they did so in an industrial way, it wasn't until user friendly systems became accessible to the public that we are starting to see its implementation in residential design. Until the appliance became mainstream, alternative versions of the technology remained on the fringe. We are now starting to see big names in home appliances adding kitchen hydroponic units to their line-up. Currently, a company named "Natufia" has what they call a smart garden [24]. An appliance designed to fit a kitchen in the same way a refrigerator could, able to grow 32 plants simultaneously with automatic watering and lighting. Designed to grow leafy greens, microgreens, vegetables, or flowers, offer a selection of 40 different seed pods. Similar appliances, like the "Smart Garden" by Panasonic, the "Home Grow" by GE, the "Smart Indoor Gardening System" by LG, and others made by smaller companies are already in the market. And while the price tag is high, the more these appliances become

mainstream the cheaper they will get. Until that happens people have been adding do-it-yourself vertical farms to their homes. In 2010 an agricultural cooperative in New York City named "WindowFarms" (started by Britta Riley) created a DIY instruction book [25]. The design presented in it was adaptive and meant to fit the typical New York brownstone 4' × 6' window. It is made of recycled plastic bottles and other materials purchased easily at any hardware store. The window farm works by using an air pump to move water with nutrients up to the top of the system. Using gravity, the nutrient rich water trickles down from bottle to bottle accumulating on the bottom where the process starts again. Thanks to this initiative and a DIY YouTube video, people started to build window farms all over the world, and a community was created. They share ideas, test different plants, and share information as a part of a process called R&D-I-Y (research and development do-it-yourself). Through this process the designs keep evolving making it easier for new members that join to build their own. A simple, cheap solution designed to provide fresh local food to people in cities. Weather we look at the high-end or the low-end version, indoor consumable plants have made their way into the home.

8 HOW IS GROWING PLANTS INDOORS SUSTAINABLE?

Sustainability is a word that is thrown around a lot, its meaning is the ability to be maintained at a certain level. In the case of food, it means that we need to grow and produce food in a way that does not deplete our resources while feeding the planet's growing population. The UN expects the world population to reach 8.5 billion by 2030 [26]. And all this people need to be able to produce enough food to subsist. The problem is that our current food production system is unsustainable. We are growing food in deforested land, bathing our crops in toxic pesticides while killing all the wildlife that used those lands previously and then we fly all that food around the world creating a huge carbon footprint for the whole process. China, India, Brazil, and the United States are the four countries that produce the most food in the world. All of them share the advantage of having large populations, a lot of land and different climate zones that allow for a variety of different crops to grow. While Ethiopia, Nigeria, South Sudan and Yemen are the countries with the highest levels of hunger and food insecurity [27]. We are running out of time; we need to figure out how to achieve sustainability for ourselves and for the sake of the environment. Indoor farming can do this in a sustainable way. And it does this first by saving resources, using hydroponic and aeroponic systems uses 90% less water than traditional farming. It also saves land because vertical farming is more efficient, taking less space which could be given back to create nature reserves. Second, we need to shorten the supply chains. If farmers can grow produce indoors, they can do so all year around, lessening the need for importing food from abroad. By buying local, we support the local economy, and the carbon footprint of our food is lessened as is the distance the food travels before it arrives to our plate. Third, because hydroponic and aquaponic systems are set in controlled enclosed environments that use no soil, there is no need for fertilizers. As a side effect, farming will stop killing insects and wildlife. And finally, the controlled environment of indoor farming protects the crop from the weather which will be important as climate change produces more extreme weather around the planet. At a macro level, cities like Singapore are already counting on urban farms to produce 30% of their food by 2030 (presently they produce 10%). Cities around the world are following their example. And while these systems are working at the macro level, a micro version of the same can be implemented on every house, especially in cities, so that families produce a percentage of their plant food helping carry the load from some of the larger systems.

9 WHAT WOULD A HYDROPONIC HOME FARM GROW?

There are many advantages to growing plants hydroponically, some were covered previously but the important one in terms of food production is the speed at which plants grow using this method. Some plants are ready to be harvested 30% to 50% faster than in traditional farming depending on the type of plant. The abundance of nutrients and extra oxygen in the water medium used for this process will also produce larger plants. If agricultural trends continue to erode topsoil and to waste water, hydroponics may soon be our only option. Depending on your socio-economic level you can either buy or build a hydroponic farm. Building a hydroponic setup at home doesn't have to be expensive and it doesn't need to take a lot of space. Here is a list of the best plants to grow hydroponically: basil, beans, blueberries, Boc choy, borage, cabbage, carnations, catnip, chamomile, chervil, Chinese evergreens, chives, cilantro, coleus, cucumber, dahlias, dill, fiddle-leaf figs, geraniums, grapes, hoya, jade, kale, lettuce, lavender, lily of the valley, lotus, mint, orchids, oregano, peppers, petunias, philodendron, pothos, radishes, rex begonia, rosemary, sage, snapdragon, sorrel, spider plant, spinach, spring onions, strawberries, thyme, tomatoes, viola, watercress, watermelon and zinnia. Fig. 1 shows the grow cycle of some of these typical hydroponic crops. Once the setup is ready, it becomes a game of research and experimentation, eventually arriving to the correct type and amount of food one wants to produce for the household. How much of this produce should we feed a person? The number is different in terms of age group, an adult should eat around 600 g of fruits and vegetables per day, this means 18 kg per month. Depending on the size of your hydroponic indoor farm and the amount of people you are feeding, one might or might not be able to achieve this number, but the purpose of indoor farms is to complement your access to fresh produce. And this, it will do at any size. Urban centres around the world suffer from "food deserts", areas where healthy food is either not available or not affordable, hydroponic indoor farming mitigates this issue by giving people the opportunity to have access to good produce at a fraction of the market price, all year round and sustainably.

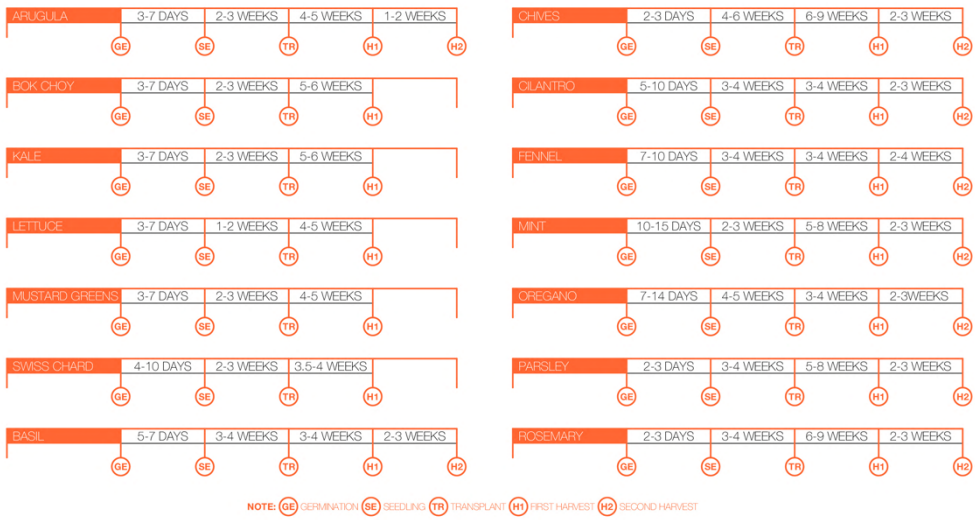

Figure 1: Hydroponic plant growth chart [28].

10 CONCLUSION

As we look into the future of dwelling, humanities coevolution with plants will remanifest indoors out of necessity. In today's fast-paced, digitized world, urban dwellers need to reconnect with nature, with something essential beyond their smart phones and social media. As millennials and post-millennials become plant parents, humanities coevolution with plants strengthens. In interiors, this relationship is more than a design aesthetic, it has complex health benefits and the potential to give people food security. As apartments and houses become sanctuaries from a fast-paced world, a place where indoor plants help enhance our mood, productivity, concentration, and creativity, while dispelling loneliness and depression, we find that indoor plants make us happier by improving our wellbeing. If on top of that they can help prevent hunger, then it is imperative to strengthen our biophilic relationship with indoor plants out of a need for survival. Hydroponic farming is not a future trend but a necessity. It is currently being taught in classrooms around the world, horticultural societies and it is being funded in government research at universities and organizations like NASA. But that is not enough, hydroponics needs to move indoors as part of interior design. So, it can help achieve food equity and the prevention of hunger, helping strengthen the United Nations sustainable development goals two, three, ten and seventeen [29]. The future of dwelling depends on plants becoming part of the interior architecture in urban centres where the city and the farm can intermix. If we are going to spend a large portion of our time indoors, whether at work or in our homes, we might as well benefit from the experience by doing so in interiors designed to better our quality of life.

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