Edited Book

Green Frontiers

Emerging Technologies for a Sustainable Future

Editors

Dr. Tanay Pramanik

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Preface

In an age marked by rapid scientific progress and increasing global challenges, the integration of knowledge across disciplines has become essential for meaningful innovation and sustainable development. *Green Frontiers: Emerging Technologies for a Sustainable Future* is conceived as a comprehensive academic work that brings together diverse fields of study to present a unified perspective on contemporary scientific and technological advancements. The book seeks to highlight how evolving knowledge systems can address pressing environmental concerns, enhance technological capabilities, and contribute to the betterment of society.

The primary purpose of this volume is to provide a balanced understanding of both foundational concepts and emerging trends across multiple domains. It explores critical issues such as environmental degradation, renewable energy development, advanced materials, and intelligent systems, emphasizing their interconnected nature.

The scope of the book is intentionally broad, encompassing insights from environmental science, physics, engineering, biotechnology, and applied sciences. It reflects the growing need to move beyond isolated disciplinary frameworks and adopt integrated perspectives that foster innovation.

This volume is designed to serve as a valuable resource for students, researchers, and professionals alike. Students will find it particularly useful in building conceptual clarity and gaining exposure to emerging areas of study.

The relevance of *Green Frontiers: Emerging Technologies for a Sustainable Future* lies in its focus on the dynamic relationship between scientific advancement and societal needs. As the world faces challenges such as climate change, resource scarcity, and technological disruption, there is an increasing demand for knowledge that is both comprehensive and applicable. It is hoped that this work will encourage critical thinking, inspire innovation, and enable readers to contribute effectively to a sustainable and technologically advanced future.

— Editorial Board

Table of Contents

“Innovation and sustainability are not opposites—they are partners in shaping the future.”

— Paul Polman

Former CEO, Unilever; Sustainability Leader

CHAPTER 8

HYDROPONICS-THE CURRENT AND FUTURE SCENARIO IN THE ART OF FARMING

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Abstract:

A modern technique of growing plants that is efficient, environmentally friendly and provides advantages is hydroponics. Hydroponics have many advantages for urban agriculture, areas with little arable land, or areas where traditional agriculture can't be done effectively. Hydroponics are a way to grow plants using a solution made up of water with nutrients instead of soil. Growing media can include perlite, vermiculite or coconut coir which provide structural support for roots as well as holding moisture and nutrients. Hydroponic systems are either classified as open or closed systems. In an open system, nutrient solution is constantly added to and drained from the container. A closed system recirculates and reuses the nutrient solution. Hydroponics is advantageous over traditional agriculture in many ways. Hydroponic systems have greater productivity, consume less water, and require lower quantities of nutrients than typical agricultural practices. Hydroponics can also be employed in locations that lack adequate soil or have no available arable land.

Keywords:

Photosynthesis, Agriculture, Macro elements, Micro elements

Introduction:

Green plants use solar energy, carbon dioxide and water via the process of photosynthesis to produce their own food and release oxygen as a byproduct. Photosynthesis is the critical biological process that allows for the establishment of the Earth's food chain as well as the maintenance of the balance between the gases that

comprise the atmosphere. Agriculture is the study of cultivating crops and raising livestock so as to grow sufficient food and other materials for the rapidly expanding human population. Both the agricultural industry and food production contribute to supporting humanity and the global economy by ensuring human survival.

Plants need nutrients to thrive. These nutrients are classified into two categories: macronutrients and micronutrients. In general, plants will require larger amounts of macronutrients than they will need of micronutrients. Some examples of macronutrients are nitrogen, phosphorus and potassium. The macronutrients are important for the growth of a plant, providing energy, and contributing to the overall health of the plant. Micronutrients are also important to a plant's proper development and functioning; however, the plants will only need them in smaller quantities than they will need the macronutrients. Micronutrients are important for several of the physiological and biochemical processes that occur within a plant as it grows. Hydroponics is becoming more popular and is labeled as an innovative way to grow plants. Because of the benefits of hydroponics compared to traditional methods of soil growing, hydroponics is becoming increasingly more popular. Hydroponic systems use nutrient solutions to grow plants; therefore, hydroponics gives you control over what nutrients your plants have access to, and gives you control over the environmental conditions of your plants as well. Hydroponics allows you to grow plants year-round, regardless of the weather; and it requires less use of chemical pest control. Moreover, because of their low water consumption and higher outputs per acre than conventionally grown crops, hydroponics can be seen as a sustainable, environmentally friendly way of producing crops. As food demands rise, available plots of land decrease, necessitating the use of modern farming methods with minimal negative environmental impact to sustain food production for future generations.

Review of Literature:

What is Hydroponics?

Using hydroponics to grow plants is a novel method that doesn't require soil; instead, it relies on nutrients mixed in with water to provide the essential minerals and nutrients that are needed by the plants at their roots. Typically, in hydroponic systems plants will

be grown in some kind of container or structure with their roots submerged or suspended from an inert growing medium such as perlite, vermiculite, coconut coir or hydroton (expanded clay pellets). The word "hydroponics" comes from the Greek word "hydro" meaning "water," and the Greek word "ponos" meaning "toil," thus the literal meaning is to toil using water. The concept of hydroponics was first developed in 1937 by William Frederick Gericke, a professor at the University of California, who attempted to produce commercially viable crops using methods he developed in his laboratory to grow plants.

Figure 1: Dr. William F. Gericke [1]

Photosynthesis Process:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

There is no mention of “soil” in the above equation. That’s all the proof you need that plants can grow without it.

Advantages of Hydroponics:

Hydroponics has many benefits to offer both commercial and home gardeners alike. One benefit of using a hydroponics system is that plants typically grow faster than those planted in soil because they have ready access to the necessary nutrients to grow without competing with weeds. Hydroponically grown plants often produce higher yields per square foot than those planted in soil due to the tighter planting density associated with hydroponic growing methods. Hydroponics is also environmentally

friendly, using water based nutrient solutions that help conserve water, minimize the use of pesticides, improve energy efficiency, reduce land usage and promote sustainable crop production. Hydroponic systems allow for the cultivation of crops in a very controlled environment, ensuring consistency and uniformity in crop quality, which makes them appealing to commercial markets that have very specific requirements for product quality. Finally, hydroponics provides an excellent research and development platform for researchers studying plant biology or agricultural science by creating a highly reproducible and controllable growing environment.

Figure 2: Benefits of Hydroponics [2]

Disadvantages of Hydroponics:

Despite the positives of hydroponics, there are negatives and hurdles that need to be assessed before growers become involved with this method of growing. Initial costs to set up a hydroponic grow system will be high, depending on the size and amount of technology used should you choose to use advanced technological options. In addition, there will be continuous operating costs to power the grow lights, pumps, and maintain the environmental control equipment. There will also be nutrient solution costs and ongoing maintenance costs associated with a hydroponic system. Another challenge that might arise is an imbalance in the nutrients; this could lead to deficiencies or too much of one type of nutrient causing damage to the plant(s). Energy consumed to run indoor hydroponic systems is also a factor; especially with the need for artificial light. Lastly, while you can grow a large number of plants using hydroponics, some plants will be more challenging to produce in hydroponics than soil farming, specifically root plants

such as potatoes and carrots.

Types of Hydroponics:

Hydroponics refers to the art of cultivating plants without utilizing soil, as is typically done in an outdoor garden. Instead, hydroponics uses different substrates, which support the roots of the plant – such as peat moss, clay pellets, perlite, or rock-wool. There are many types of hydroponic systems to help grow your plants. There are six main types of hydroponic systems that encompass all of the variations available for you to use.

1) WICK SYSTEM
2) WATER CULTURE
3) EBB&FLOW
4) DRIP SYSTEM
5) NUTRIENT FILM TECHNIQUE
6) AEROPONICS

1. Wick System:

In hydroponics, the wick system is one of the more basic systems you can use. Almost anyone can use the wick system with no requirement for electricity, pumps, or aerators. Most wick systems will have your plants directly placed in some kind of absorbent medium (such as perlite or vermiculite), then surrounding your plants are nylon wicks that will feed into the nutrient solution below. Water or nutrient solution is delivered to your plants using capillary action. This system mainly works well for small plants (such as herbs, etc.).

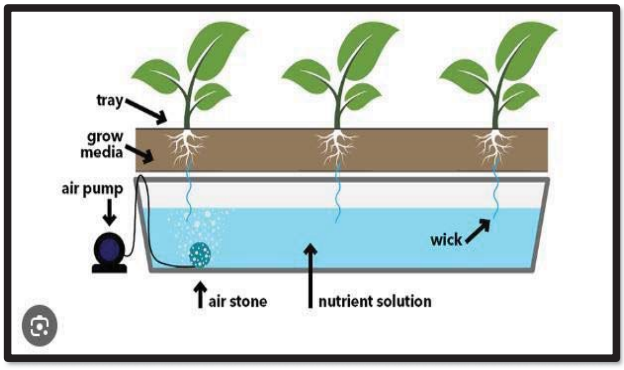

Figure 3: Wick System [3]

2. Water Culture:

A different method, commonly thought to be easier, is the water culture system. This system allows the roots of the plant to rest directly in the nutrient solution and introduces oxygen to the water utilizing an air stone or a diffuser. In contrast, the wick system uses materials such as a rope or some fibrous material between the water and the plant, while the water culture system does not provide any barriers between the two. This method is also necessary to check for oxygen and nutrient levels, salinity, and pH; otherwise, algae and mold will grow quickly in the reservoir. This type of hydroponic system will work best with larger, fruit-producing plants such as cucumber.

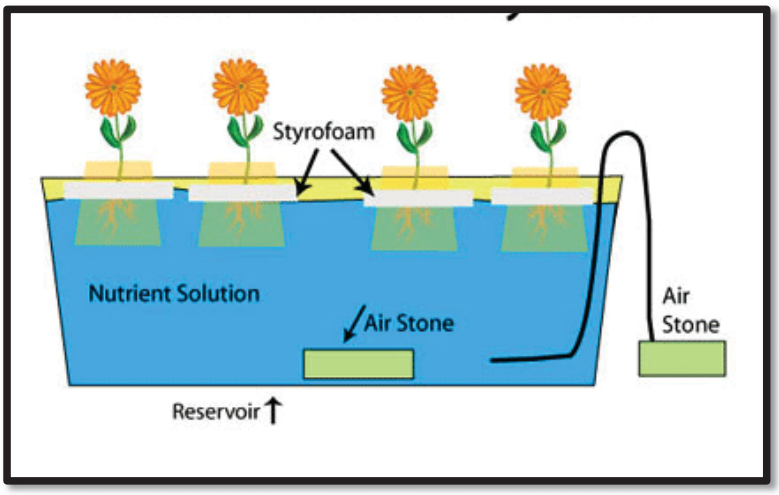

Figure 4: Deep Water Culture System [4]

3. Ebb and Flow System:

The system often referred to as a flood and drain system produces some of the most favourable growth conditions for plants. Plants in these systems are grown in a grow bed that has been filled with air as well as with a media such as perlite or rock wool. The nutrient solution is cycled through the grow bed using a pump until it reaches a certain level and then it is allowed to reside there for a period of time. This type of system allows for the cultivation of several different types of plants while being able to use some filtration system modification in the water application process.

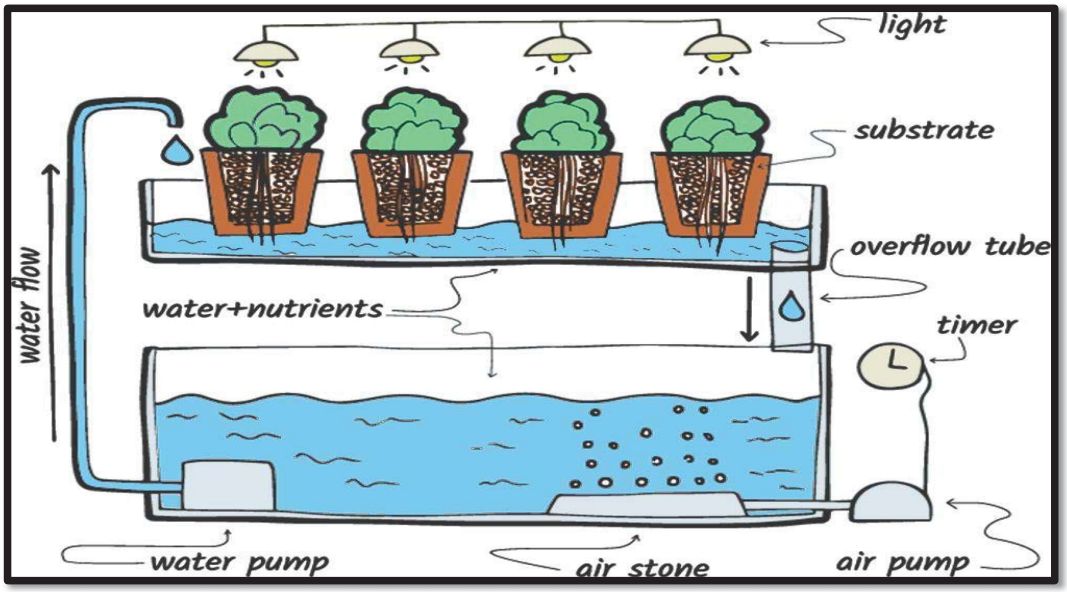

Figure 5: Ebb & Flow System [5]

4. Drip System:

A Drip irrigation is an easy-to-use hydroponic system that allows you to quickly change your system based on the different types of plants you have. This makes it very easy for any type of grower to make regular changes in their hydroponic set-up. The nutrient solution for a Drip system is pumped through a tube to the base of the plant. On the end of this tube is a Drip emitter which controls how much nutrient solution is provided to the plant. The Drip system can be used with either circulating or non-circulating solutions. If you use a circulating system, it is important that you consistently monitor and adjust the pH level of your nutrient solution as you recirculate your nutrient solution.

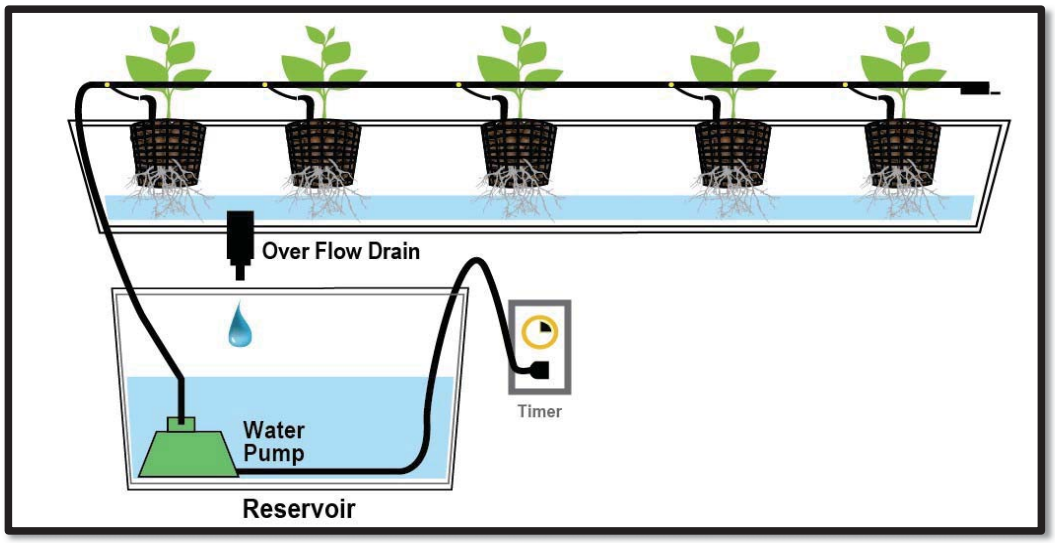

Figure 6: Drip System [6]

5. N.F.T(Nutrient Film Technology):

Dr. Alan Cooper developed NFT (Nutrient Film Technique) when it was first introduced in England in the early 1960s. NFT has a much more simplified design than the traditional ebb and flow system, and by incorporating two main components into one unit (the grow tray and reservoir), NFT allows for better management of water and nutrient solutions than either of the two systems used together. A grow tray with an angle of 1 to 5 degrees allows for adequate drainage while still allowing for good plant growth. When the water reaches the end of the grow tray, it will flow down into the nutrient return pipe and be returned to the nutrient reservoir, which will hold nutrients until the next time they need to be delivered to the plants. NFT systems are primarily designed for use with lightweight, young, fast-growing plants.

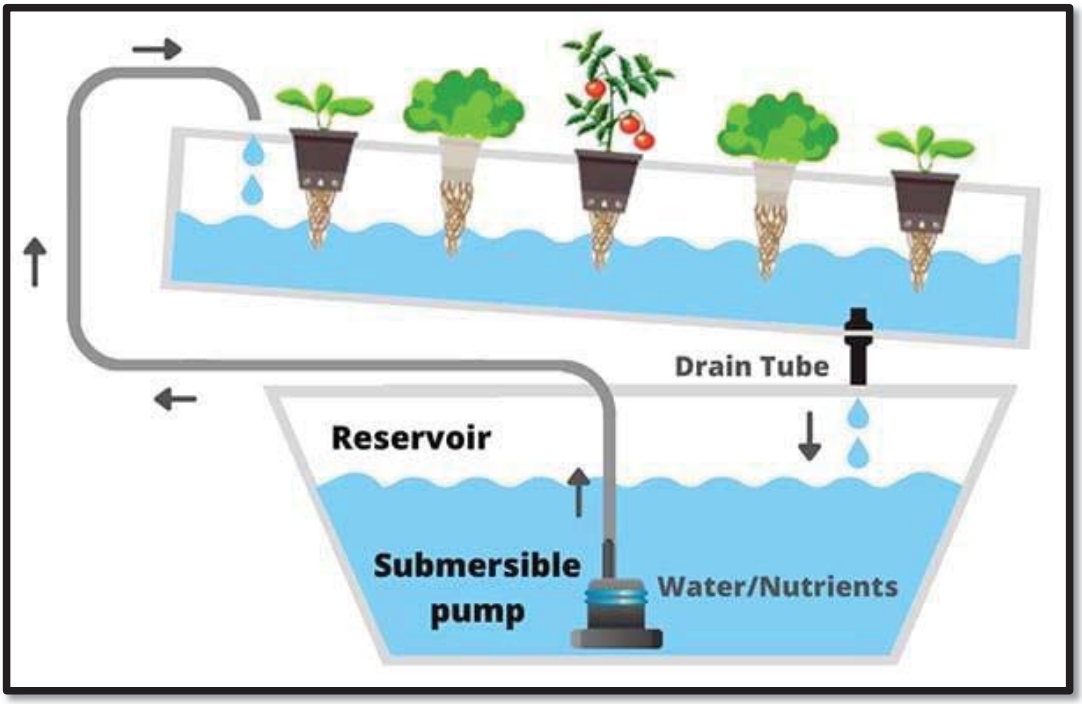

Figure 7: Nutrient Film Technology [7]

6. Aeroponics System:

Aeroponic devices utilize a variety of devices, such as sprayers or misters, to deliver a fine mist of nutrient-filled solution that can reach the roots of the plants. Aeroponics systems are closed-loop environment systems providing reliable macro and micro environments for crops grown from seed. This type of system is designed primarily for the production of numerous plants that produce roots.

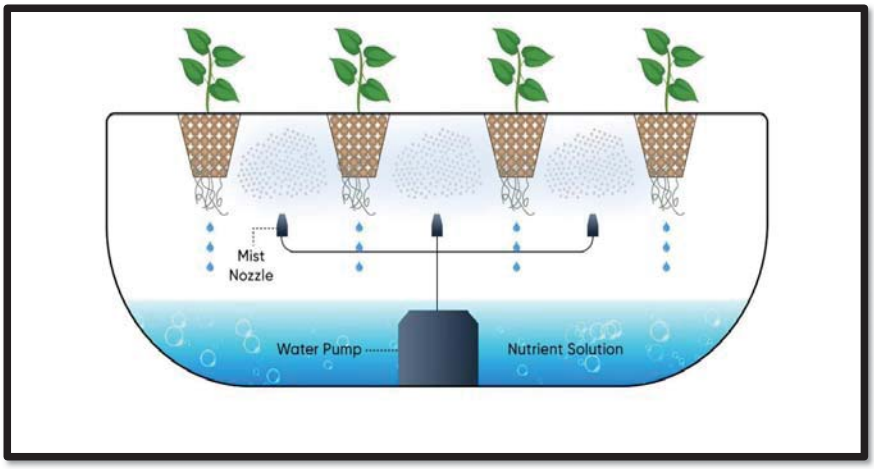

Figure 8: Aeroponics System [8]

Requirements of Hydroponics:

1. **COCO COIR:**

Coconut coir (Cocoa Coir) is one of the most popular natural hydroponic growing mediums. It's made from the inside of the coconut fruit and is an efficient soil substitute due to its high-water retention capacity, neutral pH levels, and good nutritional levels above soil.

2. **ROCKWOOL:**

Due to its fibrous nature, rockwool is commonly used for hydroponic gardening. When working with rockwool you must use a balanced pH in addition to providing plenty of water and food so that your plant roots can grow properly in a favorable environment.

3. **EXPANDED CLAY PEBBLES:**

Clay pellets (Expanded Clay Pellets (LECA)) are one of the more easily available, useable and durable crates for the hydroponic planting of plants in the hydroponic growing systems. Clay pellets can be mixed with coir to form an air-tight, non-dissolving mixture of clay, which provides a solid foundation for the roots of the plants.

4. **POTTING SOIL (PERLITE):**

Potting medium in hydroponics is an inorganic, sterile, man-made material consisting of perlite, vermiculite, and coco coir and having different essential minerals for the roots to have adequate water and air.

5. **NUTRIENT SOLUTION:**

One of the most commonly used nutrient solutions in soilless plant growth is HOAGLAND'S SOLUTION, as defined by Hoagland and Snyder in 1933, refined by Hoagland and Arnon in 1938, and revised by Arnon in 1950.

As nutrient solutions for hydroponics, growers use both nitrogen-rich grow formulas and phosphorus and potassium-rich bloom formulas to guarantee the highest quantity of crop yields for vegetables and other essential crops every time. In addition to nitrogen, phosphorus and potassium, plants will also require an additional 17 elements for optimum growth. The three elements that are most critical to plant

growth are oxygen, hydrogen, and carbon.

6. ENVIRONMENT:

Plant growth requires light, and natural sunlight is the best source of light for plants. But in hydroponic systems, especially indoors, artificial light sources (like LED, high-pressure sodium (HPS), and metal halide (MH) lamps) are commonly used to mimic sunlight. Temperature is also very important for healthy plant growth. Scientific research shows that the nutrient solution in a hydroponic system works best within a range of 65°F to 80°F (18°C to 25°C). Another key factor is pH level. The pH level in hydroponics should be maintained from 5.5 to 6.5, as this is the optimal pH range for efficient nutrient absorption by plants and will result in nutrient deficiency or death to a plant. Electrical conductivity (EC) is another measure of the overall concentration of nutrients in the nutrient solution; it provides a general indication of how available nutrients are in the solution but does not tell you whether or not there are specific nutrient in the solution or that there are specific nutrients at a certain concentration.

Nutrifresh- India's Largest Hydroponics Farm

Due to changing lifestylesand the dire need to show an illusion of growth, we, as humans, have lost our connection to Mother Earth. The majority of our food supply has become unhealthy, unhygienic and genetically modified, and at the rate our future lifestyle improvements are going, we may soon endanger our own loved ones by providing them with contaminated or 'synthetic' foods.In anticipation of the worst possible outcome, Nutrifresh has prepared itself by helping people to "break away from the chains of poor eating habits and start a well-balanced diet using Food products that are fresher, cleaner, and tastier." Nutrifresh is a group of enthusiastic young individuals who are dedicated to providing the finest, highest quality, non-GMO (Genetically Modified Organisms), and pesticide and residue-free fruits, vegetables, and herbs using the best and most current agricultural methods in the world - Hydroponic Farming Method. Nutrifresh operates its fully equipped Hydroponic Farms according to the GAB and Sustainable Growing Practices Guidelines located within Devdi, Purandhar, Pune, supported with the most modern technology, minutes away from the Highway

Mumbai - Bangalore and approximately 30 km from Pune Market Yard, and nearly 175 km North of Mumbai, at the foot of the Sahayadris mountains.

Conclusion:

Hydroponic is an innovative farming technique that has many advantages and may change how we grow food in the future. Research on hydroponic has considerable limitations, but it also offers great possibilities for researchers today looking at the future of hydroponic agriculture. Some researchers are now considering hydroponic agriculture for the future of farming on the moon. There are many methods available to overcome the disadvantages in hydroponic systems that researchers have identified. They include testing systems before planting to make sure they are functioning properly using valves and fittings correctly, closely monitoring all aspects of the system. Fertilizers purchased for hydroponic systems should be completely water-soluble (because of the high water availability) and this provides balanced nutrient availability. The area surrounding your hydroponic installation should be kept clean and orderly. A clean and orderly area will help ensure that you will be able to maintain the accuracy of your hydroponic equipment. Water can be purified by many techniques, the most commonly used method includes the use of filters to purify the water and the most successful of these methods is the use of reverse osmosis filters. Reverse osmosis systems will typically eliminate or reduce the concentration of minerals that have been dissolved into the water, however, they're often exorbitantly expensive options for purifying water through reverse osmosis systems. With the advancement of farming techniques through new technologies, especially during the present month of November, many countries are looking towards the future and starting to develop agricultural methods to grow crops on the Moon. Due to the compaction of lunar soil caused by water from the Moon, research has indicated that this creates difficulty in allowing plants to sprout from seeds. Therefore, hydroponics will probably become the best alternate option to grow food without soil.

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Emerging Technologies for a Sustainable Future

Dr. Tanay Pramanik

Dr. Tanay Pramanik is a Professor of Organic Chemistry with over 13 years of academic, research, and administrative experience at institutions such as the National University of Singapore, Lovely Professional University, and the University of Engineering and Management, Kolkata. A university silver medalist, he qualified CSIR-NET with SPM Fellowship nomination and secured top ranks in GATE and JAM. He earned his PhD from NUS and specializes in organic electronics, conjugated polymers, green synthesis, and sustainable water purification. He has over 55 SCI/Scopus publications, 20 patents, and several books and chapters. His work has received international recognition, including awards at the Geneva Inventions Exhibition. He has also held key leadership roles and contributed significantly to teaching, research mentoring, and academic development.

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