Climate Resilient Actions for Food Security for Persons With Disabilities (CRAFS 4 PwDs) Guide to Shadehouse Cultivation and Vertical Farming

Tailored for successful use by persons with disabilities

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Preface

This manual has been designed for persons with disabilities, forming a part of an integral part of the Climate Resilient Actions for Food Security for Persons with Disabilities (CRAFS 4 PWDS). The manual will provide guidance on climate-smart agricultural practices to equip readers with the knowledge and skills necessary to adopt these practices in their households and communities. It aims to empower readers rather than merely impart agricultural knowledge. The reader is taking a significant step towards resilience and self-sufficiency by accessing the information contained within. By utilizing this manual to develop skills in agriculture, readers are presented with an opportunity to secure a steady source of income, gain food security and foster stronger bonds with the community. This project is proudly funded by the Global Environment Facility (GEF) Small Grants Programme, implemented by the United Nations Development Programme. The project is being executed by the Guyana Council of Organisations for Persons with Disabilities (GCOPD).

Purpose of the Manual

The primary goal of this manual is to provide readers with step-by-step guidance and practical tips on shade house cultivation and vertical farming. These modern agricultural techniques offer numerous benefits including increased crop yield, efficient use of space, and the potential for year-round production. The components of shade house cultivation and vertical farming are described, and steps are provided on how the reader can set up, manage and maintain a shade house or utilize vertical structures for agricultural purposes. By mastering these methods, the reader can improve food security, support sustainable agricultural practices, and create new opportunities for economic independence.

Learning Objectives

1. To aid in your familiarization with the types of shade houses applicable to Guyana.
2. To be able to determine which shade house is best suited for you.
3. To know the type of crops suited for shade houses.
4. To understand how to cultivate and manage the crops planted.

5. To know what irrigation systems are best suited for shade houses.
6. To learn about vertical farming systems

Why is the concept of Shade-house cultivation being introduced to you?

As climate change continues to impact agriculture, particularly in the Caribbean, farmers face numerous challenges such as rising temperatures, prolonged droughts, and increased pest infestations. These factors threaten crop yields, food security, and livelihoods across the region. One effective solution to combat these challenges is the use of shade houses in agricultural practices. Shade houses offer a controlled environment that provide:

- **Temperature Control**: By shielding crops from intense heat and sunlight, some shade-houses create a controlled environment that lowers heat stress and promotes healthier plant growth.

- **Water Conservation:** In areas with dry climates or during periods of drought, the shade from the shade houses help to lower evaporation (or

prevents too much water from being released from the plant or soil and absorbed into the atmosphere), which results in more effective water utilization and conservation.

- **Pests and Diseases Management:** Shade houses can help minimize pest infestations and slow the transmission of diseases by acting as a physical barrier from outside infected crops which will improve crop health and yields.

- **Extended Growing Seasons:** By creating a stable environment which is favourable to plant growth, shade houses help farmers extend the growing period and enable the year-round cultivation of some crops.

- **Agricultural Diversification:** Growing crops in shade houses increases the number of plant varieties which can be cultivated.

Characterization of a Shade house

Rule of the thumb specifications of shade houses.

Shade houses can be divided into 2 main categories: Fully Enclosed and Open-sided shade house.

Fully Enclosed shade houses can be tailored to suit the crops. In this type of shade house, all four sides as well as the roof is covered with an insect-proof mesh. This may or may not be covered with plastic depending on the crop planted. The main objective here is to keep out insects. These are applicable to leafy vegetables and self- pollinating crops (does not need insects to pollinate the flowers), for example, cabbages, celery, lettuce, peppers etc.

Figure 1: Illustration of a fully enclosed shade house. (*Source: The Glasshouse Company)*

Open-sided shade houses are applicable where pollinators are needed to help with pollination and fruit set. Bora, however, is a unique case where a fishing net is used to enclose the shade house to prevent birds from eating the flowers but allow bees through.

Figure 2: Photo of an open-sided shade house

Shade nets are used when plants yield more under shaded conditions e.g. celery and peppers. Shade plastic is used to keep off rain which increases the occurrence of diseases. Lettuce, saame, bora and cucumbers are crops that need protection from the rain but need full sunlight. While plastic lets sunlight pass through, it does block some amount of ultraviolet radiation. The shade house offers some help with natural temperature management except where fans and other temperature management systems are applied.

While the length and width vary with affordability and space, it is usually good to keep the width so that one side of the roof is (the length of your rafter) at 85% of the width of the plastic and shade mesh, as it is not advisable to join the plastic along the width of the roof. Generally, the lowest point of the roof should be 10 feet above the ground and the throw of the roof should be at a ratio of 1 to 4, meaning for every 4 ft of one side of the shade house the peak of the roof should be raised 1 foot. It is necessary to advise the builder of these parameters.

Figure 3: Shade Net *(Source: amazon.co.uk)*

Figure 4: Shade Plastic (Source: drairatxediaz.com)

Monoculture is best suited for shade houses since it helps with an all-in all-out system. Furthermore, a shade house can be best adjusted to suit the crop. Having multiple crops in a shade house will likely cause one crop to affect the other.

Shade house Designs

1. **Fully enclosed tunnel type.**

Figure 5: A fully enclosed tunnel type shade house *(Source: Redpth New zeland website.)*

The entire structure is covered with insect proof mesh and the vent at the top allows hot air to escape.

2. **Simple net house**

Figure 6: Photo of a net house on a farm

No sloping roof because there is no need for rainwater to run off.

3. The open-sided Jack roof type

Figure 7: Photo showing a jack roof type shade house

This is the most common type of shade house in Guyana.

Key to help you decide on the type of shade houses to use:

Crop	Shade mesh	Plastic	Mesh + Plastic	Design		
				All designs applicable	Open side	Enclosed sides
Bora	x	√	x	√	x	Fishing net

Cabbage	x	√	√	√	x	Insect proof mesh
Celery	√	√	√	√	x	Insect proof mesh
Chinese Cabbage	√	√	√	√	x	Insect proof mesh
Cucumber	x	√	x	√	√	x
Hot Pepper	√	√	√	√	x	Insect proof mesh
Lettuce	√	√	√	√	x	Insect proof mesh
Pak choy	√	√	√	√	x	Insect proof mesh
Saime	x	√	x	√	√	x
Sweet Pepper	√	√	√	√	x	Insect proof mesh
Tomato	x	√	x	√	√	x

Step-by-Step Guide to Shade House Set Up

A well-constructed shade house creates a controlled environment that supports healthy plant growth. This step-by-step guide will walk you through everything you need to know, from choosing the right location and selecting the proper materials to installing shade mesh and optimizing your shade house for different crops.

1. **Select Location:** The shade house should be placed in an area that provides enough sunlight for the crops while also providing some protection from intense heat or wind.

Figure 8: Illustration showing the selection of a site

2. **Orientation:** Shade houses are best oriented from east to west lengthwise. This allows a good flow of wind and prevents direct sunlight from hitting your plants early in the morning and late in the evenings.

3. **Getting the ground ready:** The shade house should be positioned on level ground. Clear the area of any shrubs, waste or obstructions. Ground cover may be spread if grow boxes are used. This may not be applicable if the beds are established directly on the floor.

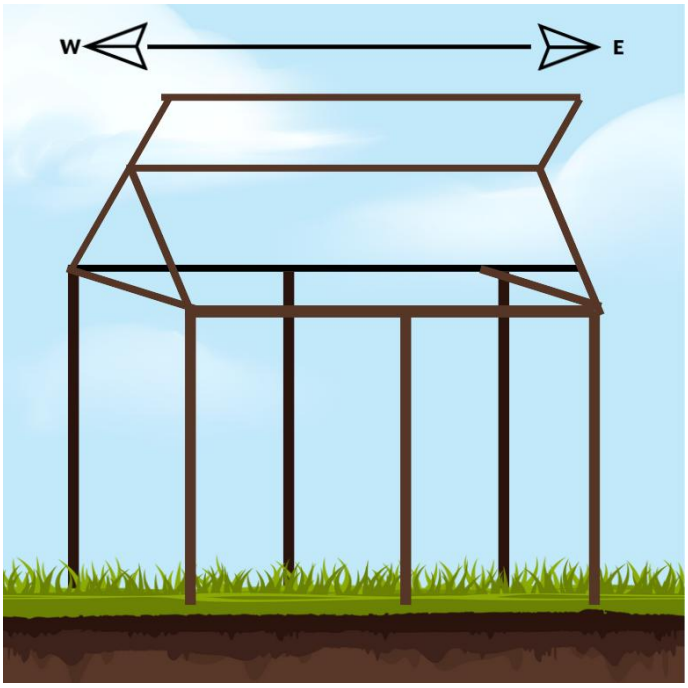


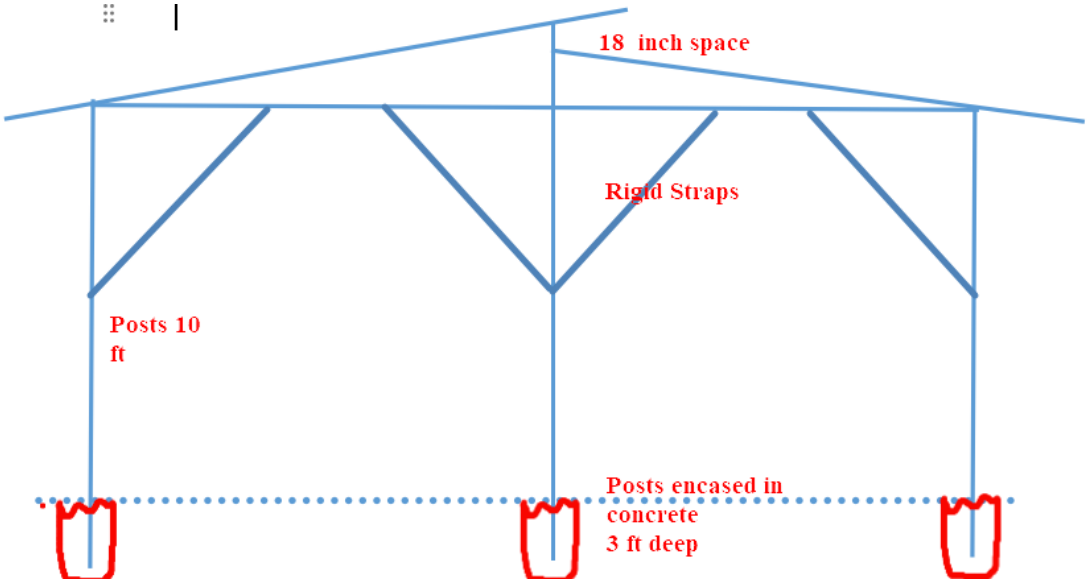
Figure 9: Illustration of deal orientation and ground for a shade house frame

4. **Assemble the Frame:** The shade house frame consists of the roof and posts which should be correctly aligned and fastened. Metal or plastic fittings are used to join different parts of the frame together, such as corner connectors and beam brackets.

   Posts are spaced 10 feet apart and are strapped with wooden straps to prevent rocking. In the case of metal frames, brackets must be used to prevent rocking.

5. **Install Anchoring System:** To anchor the shade house to the ground, place stakes or anchors at the proper intervals around its perimeter, depending on the type of anchoring system which was chosen. It is best to insert posts in the ground and pour concrete around them.

6. **Single-length rafters**: should be used to prevent damage to the plastic. Further, no sheath laths are recommended.



Figures 10: Diagram illustrating steps 4-6

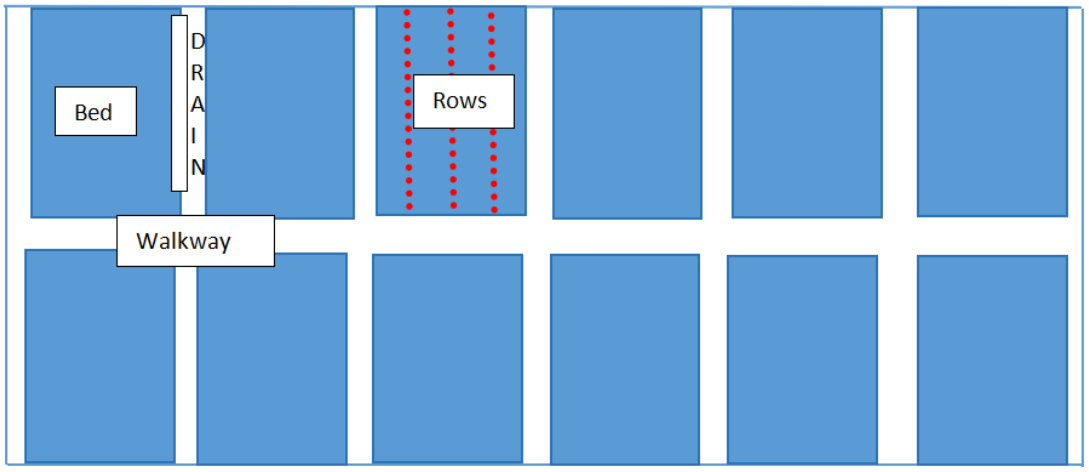


Figure11: Diagram illustrating steps 4-6

7. **Attach Shade Netting:** Tightly and firmly connect the shade netting to the shade house frame by stretching it over the frame and fastening appropriately. A similar approach should be taken for plastic.

8. **Secure Edges:** To prevent the shade netting from being displaced by the wind or other factors, connect the edges of the netting to the frame with clips, ties, or other fastening techniques.

Figure 12: Illustration of steps 7-8

9. **Check Stability:** After the shade house is assembled completely, check its stability and make any required modifications to ensure it is firmly anchored and built correctly.

Bed Preparation

- If you are planting directly on the ground, soil must be forked, and the bed prepared like a garden bed.
- Soil should be chipped and cleaned with weed remnants.
- Soil should be sampled and taken to the National Agricultural Research and Extension Institute (NAREI) for lime recommendation. If this cannot be done, a generous application of limestone at about 250g per square foot could be evenly spread and incorporated into the soil. Beds should be no more than 36 inches wide and as long as possible within the shade house. The spacing between beds should be at least 24 inches to allow easy access to beds for tendering and harvesting.
- If grow boxes are used, please follow the instructions above. The procedure is similar for pots as well. Boxes should be between 8 to 10 inches deep.

- If any organic matter, compost, cow mould, or chicken mould is desired then it should be added at this stage. Remember to only use well-rotted cow mould or chicken mould. The mould should not have a bad smell since bad smells indicate that the mould is not well rotted.
- Once beds are prepared, mulch may be added to suppress weed growth by blocking sunlight and preventing weed seeds from germinating. If this procedure is done with peat moss or plastic mulch, planting can begin immediately. If an organic mulch is used, then it is advisable to wait 3 days before planting.
- This is the time to install the irrigation system if such a system is to be used.
- Soak beds with clean water, thoroughly before planting.

Figure 13: Well prepared beds *(Source: iStock*

Irrigation systems

Irrigation systems are a critical component of shade house cultivation. Irrigation is the most important system in a shade house. The type of irrigation system used would be dependent on the crops grown, the cost and the size of the shade house.

Types of irrigation systems:

1) **Pump and garden hose**

This is a system where a pump (electrical or otherwise) attached to a garden hose and connected to a source of water is used. The garden hose is connected to a spray nozzle. In this type of irrigation system, a person will have to hold the hose and water the bed directly. These are applicable for small shade houses.

Figure 14: Photo showing someone using the pump and hose system *(Source: Pet Poo Skidoo on YouTube)*

2) Sprinkler system

In this system, water is pumped from a source to PVC pipes that are connected to sprinkler hoses. Once the pump is turned on the pressure within the system causes the sprinkler to spray. It is not advisable to use lawn sprinkler systems in a shade house since water must be concentrated on the beds and not create mud in the walkways. These are applicable to larger shade houses.

Water source -Pump- PVC Pipe - T valve- Sprinkler hose

Figure 15: Sprinklers *(Source: AGRIVI)*

3) Drip irrigation

Drip irrigation is diverse in designs and applications. They range from simple drip tape to more pressurized dispensing systems.

The simple drip tape system is one in which a flat plastic hose is laid directly on the rows where the seedlings are planted on the bed. The drip hose (drip tape) has small holes at intervals. Water is pumped through a PVC Pipe that is connected to each drip hose. At a certain pressure, the water begins to drop out of the hose and onto the soil. This system does not waste water, and it is easy to manage. The only setback is that the orifices on the drip tape block easily. However, to clean inside the drip tape farmers force a small piece of sponge in the line and then turn the pump on. The sponge cleans the line as it passes through.

Figure 16: Typical layout for a drip irrigation system

Getting Ready to Plant:

Depending on the type of crops planted, different spacing is required. Please see the table for spacing below.

Crop	Spacing Between plants	Spacing Between rows
Bora	18 in	24 in
Boulanger	24 in	24 in
Cabbage	18 in	18 in
Callaloo	6 in	6 in
Celery	3 in	3 in
Chinese Cabbage	10 in	10 in
Cucumber	24 in	36 in
Hot Pepper	12 in	12 in
Corilla	60 in	60 in
Lettuce	6 in	6 in
Ochro	12 in	12 in

Pak choy	6 in	6 in
Saame	72 in	72 in
Squash	72 in	72 in
Sweet Pepper	12 in	18 in
Tomato	12 in	12 in
Watermelon	36 in	60 in

- Under shade house conditions, direct seeding is not recommended as differences in temperature and other environmental conditions may affect germination.
- Seedling could be either bought directly from a nursery or seedling may be set in trays to be transplanted into the shade house.
- Once seedlings are present, remove all weeds that may come from the nursery to prevent importing weeds.
- Using a small stick, create little holes in the soil about 2 inches deep and 1 inch wide.
- Gently insert seedlings by the root into the holes one plant at a time,one plant per hole.

- Gently cover the hole with soil. Be careful not to damage the plant in doing so.
- Do not press the soil around the root since this may cause compaction too close to the root.
- After planting is complete, give generous watering while at the same time avoid too much water.

Figure 17: Example of seedlings planted in a bed

Husbandry

- For the first 3 days, beds must be always kept damp, and watering may be needed twice daily. Apply water on a regular basis to always keep the beds damp.

- Inspect for pests and diseases. If treatment of beds is followed, minimal occurrence of pests and diseases may be found.

- Critical at all stages is to prevent attacks by animals such as goats, sheep and cows.

- Replace any dead, dying or heavily diseased or damaged plant.

- Apply small amounts of organic fertilizers like manure on a weekly basis to continuously feed the plant.

Some common pests to look for:

Name	Photo	Description
Aphis	 *(Source: InfluentialPoints)*	Tiny insects attached to the bottom of leaves and on stems.

White flies	 (Source: Gardeners Basics)	Tiny moths attached to the underside of leaves. Common to Boulanger, cauliflower, Broccoli etc.
Stink bug	 (Source: Gardening Know How)	These are generally found on the top, tender parts of your plants.
Caterpillars	 (Source: Nature Museum / Chicago Academy of Sciences Blog)	They come in all different shapes and sizes. They tend to chew at the leaves and growing tips of plants.

Cutworm	 *(Source: Bugwoodwiki)*	These live in the soil and come up at night to feet. They tend to cut the plants early in life. They have charismatic coils as seen in the picture.

Common diseases to look out for:

Name	Photo	Description
Damping off	 *(Source: Vegetable Crops Hotline)*	Attacks the lower stem of plants. Symptoms include discoloration, softening, shriveling and falling over plants.
Anthracnose		Small dried-up spots on leaves, fruits and stems.

	 (Source: The Morton Arboretum)	
Blossom end rot	 (Source: Grow Tomatoes Easily)	Common in tomatoes and peppers. The disease is caused by a shortage of calcium.
Soft rot	 (Source: plantsdb)	While it does affect leaves and stems, soft rot is destructive to fruits.
Late blight disease		The first symptoms of late

	 *(Source: Pittsburugh Post-Gazette)*	blight tomato leaves are irregularly shaped, water-soaked lesions, often with a lighter halo/ ring around them

For diagnoses and management of diseases and pests, it is best to contact your Local Extension Officer.

Pruning:

Pruning is a critical process in shade house cultivation. It enhances growth and production while at the same time preventing diseases and pest attacks.

This may include the removal of old diseased leaves to the removal of stems. In crops like peppers, boulangers, tomatoes etc., pruning is a critical aspect. Readily available procedures for pruning each crop are present on YouTube, or Google and the procedures can be easily found.

Figure 18: Illustration demonstrating pruning

Staking:

Staking in crops like sweet peppers, tomatoes and boulangers is critical since the weight of the fruits produced cannot be supported by the plants themselves. When fruits touch the ground, they tend to rot or get damaged. Staking can be achieved by inserting a rigid stick into the ground and using a nonabrasive string to tie the plant onto the stack. The tie should not be too tight to cause injury nor too slack to cause the plant to slip. Best to place the string at a point where the plant may buckle. Several ties may be required as the plant grows. Staking should commence early in the plants' life to prevent damage when doing it.

There is no need to use expensive lumber for staking. A piece of bamboo, old wood, stiff tree branches etc. are perfectly suited for this.

Figure 19: A plant that has been staked

Trellising/ Harbouring:

Vine crops such as cucumbers, bora, corilla, squash etc. do not have rigid stem structures and tend to run on the ground. However, under shade house conditions where there is limited space, and to make crop management and harvesting easier,

these crops need support as such, a harbour needs to be built. In shade houses, this can be done mainly by trellising. This is where posts are inserted into the ground along the rows where the crop is grown. Nets may be hung or a network of twines strong enough to support the weight of a bearing vine can be used to provide the crop with a structure to climb on. Old, big-eyed fishing nets can also be used supported by a strong wireline. Posts must be firmly anchored to the soil and strapped to prevent movement.

Figure 20: Trellising of cucumber plants

Management at flowering:

The next important stage in the plant's life is flowering. Unlike leafy vegetables, where they can be harvested when they are at the desired size, fruit plants go through a stage of flowering. This is a stage where careful management is necessary since the plant is at its most vulnerable state. A flowering dose of nitrogen, phosphorous, potassium, and magnesium in a ratio of 12:12:17:2 respectively is needed to help with flower retention. Expect bees and wasps to visit the flowers, so it might be wise to observe your plants carefully. Be on the lookout for stink bugs, as they are known to attack flower buds. Left unattended, stink bugs can cause total drop-off and significantly reduce your yield. Fungal infections may also affect flowering. At this stage, it is recommended to apply natural fungicide, such as a mixture of baking soda and water, along with insecticidal soap or neem oil to manage pests in an eco-friendly way. For most fruit-bearing plants, a weekly application of organic fertilizer with a balanced ratio, such as 12:12:17:2, can help maintain fruit production. This is the stage where watering is critical since the plant will demand water; a shortage of water will result in a flower drop. Regularly check the soil moisture and ensure consistent watering to support healthy growth and flowering.

Harvesting

Harvesting is the point at which you will reap the reward for your hard work. Careful consideration must be given to the quality that is required by your markets. These may include a certain size, or a certain state of ripeness etc. The time between harvests will vary from crop to crop. Bora and ochro are harvested every other day. Tomatoes, peppers, corilla, squash are harvested twice weekly etc. Harvesting is best done in the cool, either early morning or late in the evening. When produce is harvested it is recommended that they be allowed to air -off for about an hour in the cool shade, to bring them to room temperature. It is advisable not to wash it until it reaches the market. Washing will encourage fungal and bacterial infection because the produce now has no defense. Produce must be dispatched to the market or cold storage as soon as possible to avoid losses. Post harvest losses are one of the biggest losses in the agriculture industry. It is critical that handling be gentle to prevent mechanical damage such as bruises and smashing. Best to pack in boxes, baskets and harvesting trays. Transporting produce should be done in an airy shaded vehicle or with AC.

Marketing your produce:

Marketing produce can be done by retail or wholesale. It is critical to check with other sellers to determine the prevailing prices before putting out your produce for sale. Always keep your produce neat and clean because shoppers are more akin to buying nice fresh-looking fruits and vegetables.

Pictorial Guide to help you recognize some common crops in Guyana.

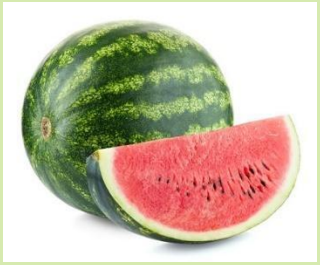
Name	Plant	Produce
Bora	 (Source: Depositphotos)	 (Source: Cooking with Shindy)
Boulanger		

	 (Source: Adobe Stock)	 (Source: shutterstock)
Cabbage	 (Source: Greenlife Crop Protection Africa)	 (Source: iStock)
Callaloo	 (Source: Walmart)	 (Source: Guystar Online Shopping)

Celery	 (Source: Ugaoo)	 (Source: Vibrant Farm)
Cucumber		 (Source: iStock)
Hot Pepper	 (Source: Southern Living)	 (Source: Truff)

Corilla	 (Source: Village Voice News)	 (Source: Adobe stock)
Lettuce		 (Source: Shutterstock)
Ochro		

	 (Source: 123RF)	(Source: Dreamstime)
Pak choi	 (Source: Urban Farmer)	 (Source: iStock)
Sweet Pepper	 (Source: Bonnie Plants)	 (Source: Pixabay)
Tomato		

	 (Source: Makkeelijke Moestuin)	 (Source: Adobe Stock)
Watermelon	 (Source: iStock)	 (Source: Adobe Stock)

Some Setbacks of Using Shadehouses

- Requires an upfront capital investment in material and labour for construction depending on the type and size of the shade house.
- Planting the wrong varieties can result in lower yields and even death of crops.

Vertical Farming

It's no secret that the future of agriculture is concerning and needs a change. Overall, the population is growing at about 1 per cent per year, even faster in some countries. Feeding this growing population is sure to be a challenge as time progresses.

We must find better ways of producing food for future generations. Fortunately, new farming technology, such as vertical farming (agriculture), offers an excellent way to meet these challenges and produce the food needed for future generations. Vertical farming is exactly what it sounds like farming on vertical surfaces rather than traditional, horizontal agriculture. By using vertically stacked layers, farmers can produce much more food on the same amount of land (or even less).

Vertical farming can be done in the open or in structures such as shade houses, green houses, regular buildings etc. In fact, one form of vertical farming has been done for ages: putting trellising for bora, corilla and passion fruits is a form of vertical farming. However, the concept has radically changed over the years. In current vertical farming, crops grow vertically in a fully controlled environment.

The practice now employs artificial temperature, light, water, and humidity control. A delicate balance is maintained to encourage drastically improved production. To emphasize the level of efficiency in agriculture, please take a close look at Figure 21 below:

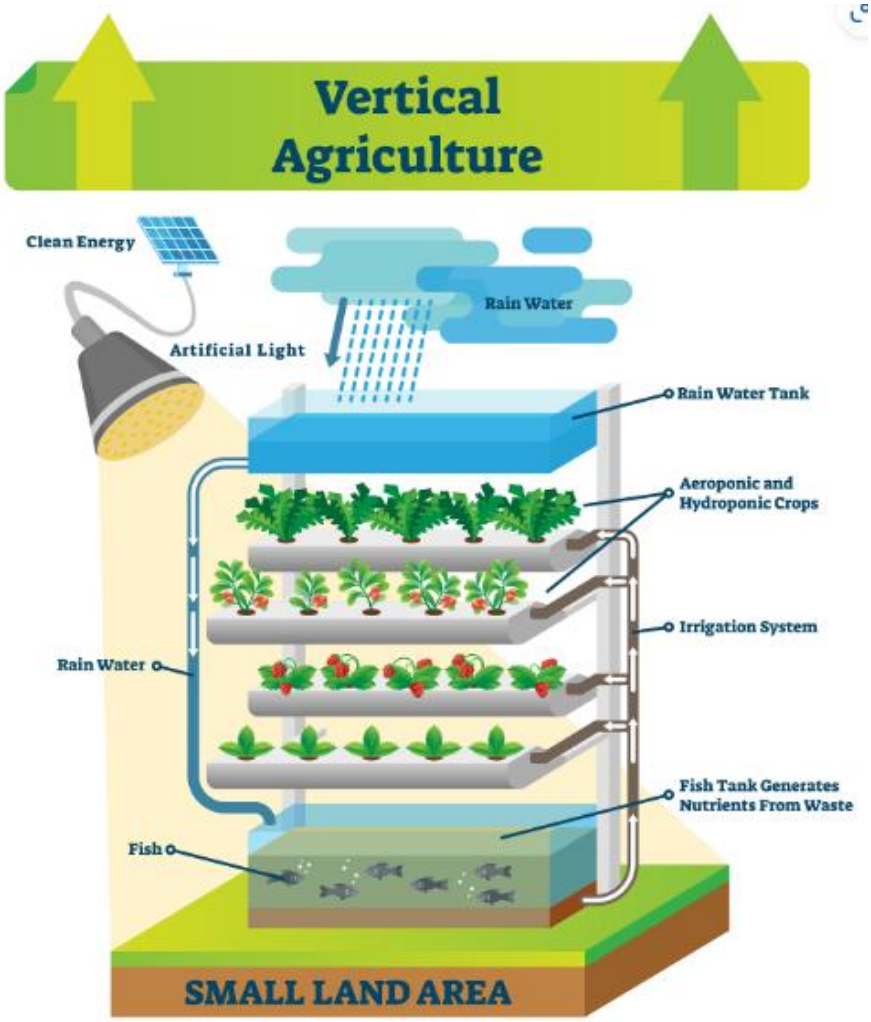


Figure 21: Diagram illustrating a typical vertical farming setup *(Source: medium.com)*

The technology ranges from real high-tech approaches to basic pot-on-a-stand systems. The one setback is that it is limited to certain crops, and it is expensive to do large scale production, for example vast open fields of crops like rice and sugarcane and corn. However, with improvements in technology and the demand for more food, there will come a time when it will be possible to do very large-scale vertical farming.

Types of Vertical Growing Systems

1. **Soil medium**

This is a simple system of vertical farming that is very limited to the crops that are grown and the scale of production. In this system, soil is placed in pots or other containers and plants are grown in them on an inclined plain to capture sunlight. This system may be implemented in a shade house or an open area. The critical factors in consideration are the cost, practicality and light incidences. However, it has been a very successful system on a small scale.

Figure 22 below gives a conceptual view of the system. All practices of traditional agriculture are applicable to this system.

Figure 22: Example of vertical gardening with soil.

1. Soilless medium

There are three soilless growing methods for vertical farming: hydroponics, aeroponics, and aquaponics. While soil culture is simple and easy to work with,

soilless culture requires advanced training and large capital for investment. As such, this manual will only provide a conceptual perspective of soilless culture.

a. Hydroponics

Hydroponics is a method of growing plants without soil, using water, nutrients, and light. The nutrients are dissolved in the water and the solution is aerated. The picture below gives a good concept of it.

Figure 23: Photo of a hydroponics system *(Source: Home Grown Farm)*

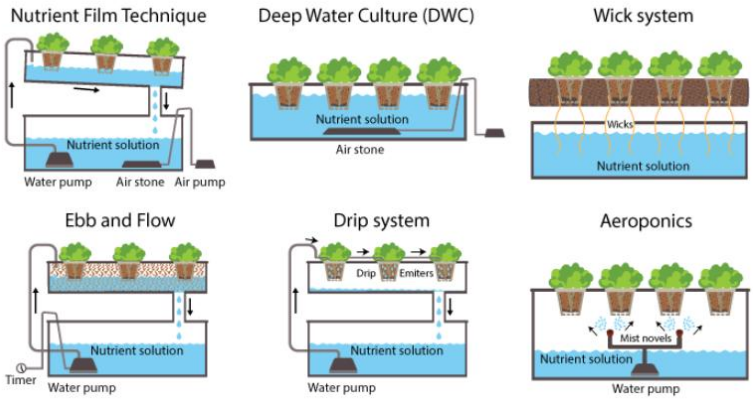


Figure 24: Types of hydroponic systems *(Source: Akash + BYJU'S)*

While the media is conceptually watering, an inert filler may be added to provide anchorage. These fillers may be rock wool, sand, gravel or any non-absorbent material that does not contribute to the nutrient status of the solution.

b. Aeroponics

Aeroponics is an advanced variation of hydroponics where plants are suspended in the air, and their roots are periodically misted with water from a timed sprinkler system connected to a main nutrient reservoir. The diagram below gives a good concept of it.

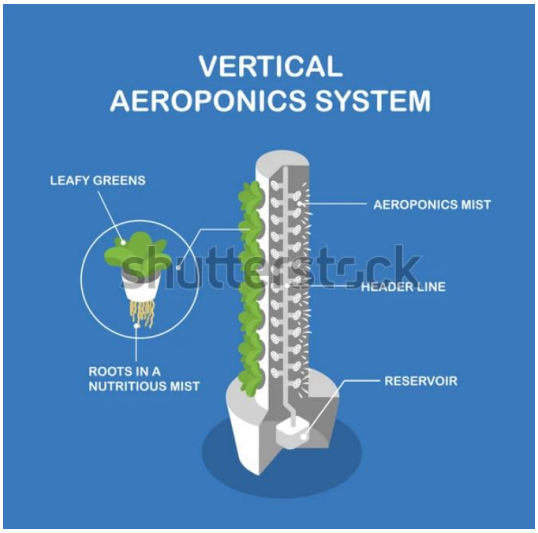


Figure 25: Diagram of a vertical aeroponics system *(Source: Shutterstock)*

c. Aquaponics

Aquaponics is a unique farming method that combines aquaculture, the practice of raising fish, with hydroponics, the method of growing plants in a soilless environment. In an aquaponics system, fish and plants are cultivated together in a symbiotic environment where they mutually benefit from each other's presence. The waste from fish tanks generates nutrients for the plants. However, the fish must be fed to produce waste.

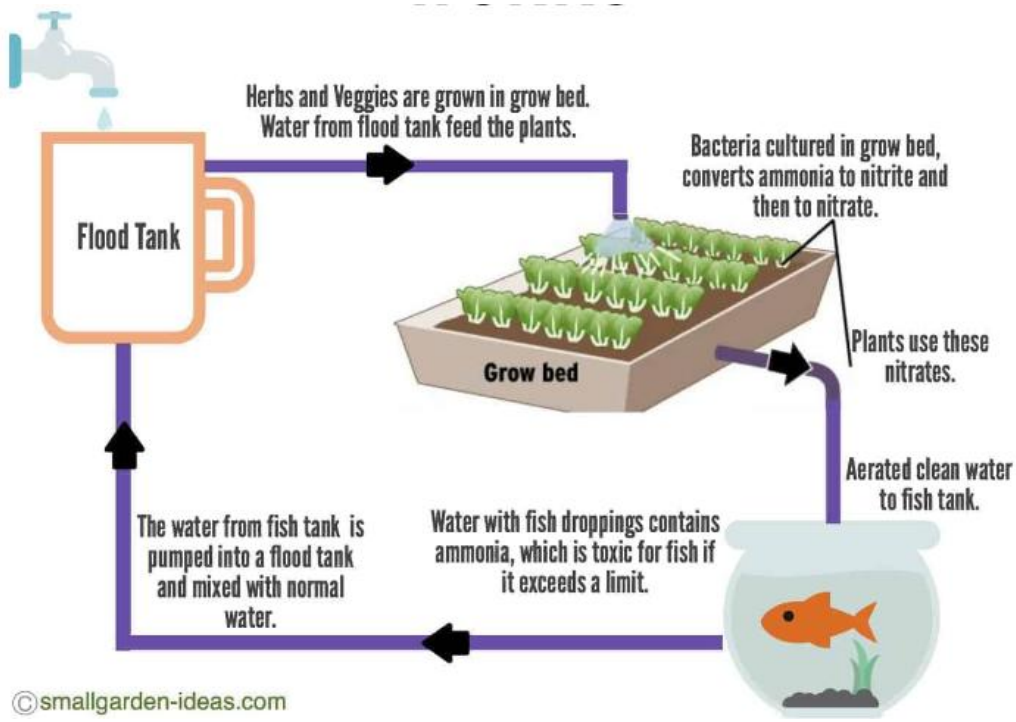


Figure 26: Diagram showing how aquaponics works *(Source: smallgarden-ideas)*

Fish produce waste primarily in the form of ammonia, a byproduct of their metabolism. Ammonia is toxic to fish at high levels, so it needs to be efficiently removed from the water. In an aquaponics system, this waste is the starting point of the nutrient cycle that benefits plants.

Beneficial bacteria play a critical role in aquaponics by converting toxic ammonia into less harmful nitrates, a process known as nitrification. These bacteria colonize the surfaces within the system, particularly in the grow bed media and biofilters. The establishment of a robust bacterial colony is crucial for the system's stability and efficiency.

Plants absorb the nitrates and other nutrients from the water through their roots. As they take up these nutrients, they clean and filter the water, which is then recirculated back to the fish tank. This nutrient uptake supports plant growth and productivity allowing for the cultivation of a wide variety of crops. The choice of plants can range from leafy greens and herbs to fruit vegetables, depending on the system's design and environmental conditions.

In all the systems, there is no need to apply solid fertilizer as when cultivating on the soil. The nutrients are specially formulated mixtures that are dissolved in the nutrient solution. There is little or no need to use pesticides when growing indoors. Critical to this system is the provision of appropriate lighting conditions for photosynthesis to take place. However, considerable precautions must be taken to prevent the entry of pests and diseases into the enclosed environment. Because the environment is heavily modified, and the crops are of high yielding varieties, indoor vertical farming is indeed more productive.

These systems have been found to be very adaptive to indoor cultures where everything provided for the plant is man-made. Since limited floor space is available in buildings, the system must maximize the available space. As such, these systems lend themselves to vertical production. A single square meter of floor space

can now produce 5 or ten times what is produced in a horizontal system as illustrated in Figure 26 below.

Advanced Vertical agriculture

In a world where arable land dedicated to feeding people is becoming a scarce and expensive commodity, agriculturists and other scientists must come up with solutions for improved food production. While these technologies are currently advanced technologies today, they will change in the future and as such it is critical to keep up research and training for a better life for all.

Figure 26: Large scale advanced vertical agriculture *(Source: LinkedIn)*

Resources

1. CRESIAP, Tlaquepaque, Mexico
2. Training Manuals
3. Personal Notes from an expert on shade houses, Rohit Singh
4. Redpath New Zealand. (www.redpath.co.nz)
5. Protected cultivation, Net Houses, Net Houses (jainpipe.com)
6. Drip System Installation - Sprinkler Installation Phoenix (sprinklerinstallphoenix.com)
7. 59 Different Types of Vegetables and Their Nutrition Profiles (nutritionadvance.com)