MTP-2 Report (TD696)

On

Design, Analysis, and Demonstration of Entrepreneurship Model of Nutri-Garden through Low-Cost Bamboo Polyhouse as Add-On to Nutri-Garden

A Dissertation

Submitted in partial fulfillment for the Degree of

M. Tech. in Technology & Development

by

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Certificate

This is to certify that the MTP-2 report titled "**Design, Analysis and Demonstration of Entrepreneurship Model of Nutri-Garden through Low-Cost Bamboo Polyhouse as Add-On to Nutri-Garden**" prepared by Dnyaneshwar Uddhav Sanap is approved for submission at Centre for Technology Alternatives for Rural Areas (CTARA), IIT Bombay, Powai.

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I further declare that this written submission represents my ideas in my own words and where other's ideas or words have been included, I have adequately cited and referenced the original sources. I affirm that I have adhered to all principles of academic honesty and integrity and have not misrepresented or falsified any idea/data/fact/source to the best of my knowledge. I understand that any violation of the above will cause for disciplinary action by the Institute and can also evoke penal action from the sources which have not been cited properly.

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Date: 28th March 2021 Signature of the Candidate

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ABSTRACT

Agriculture directly connects with nutrition. Even though agricultural productivity is growing day by day, malnutrition in India is not reducing. The reason lies in the hidden hunger. Children and women in rural India are deficient in micronutrients. These micronutrients come from the diversity in the diet. To achieve the minimum dietary diversity, Kitchen Garden / Nutri-Garden's intervention is promoted by various government and non-government organizations. This project starts with finding the constraints faced by Nutri-garden growers by conducting field visits and interviews based on a structured questionnaire. Further, this project attempts to overcome farmers' constraints in getting year-round production through Nutri-Garden. For this, the solution of Bamboo-Polyhouse is demonstrated in the Jawhar and Vikramgad blocks of Palghar district in Maharashtra.

This document reports the design, analysis, construction details, and performance analysis of the bamboo-polyhouse. The bamboo-polyhouse was found to be safe against wind speed of 44 m/s when analyzed in ETAB software. The construction and joinery details are reported in this document. The microclimatic parameters (temperature, humidity, and wind speed) were measured at the polyhouse sites. The maximum temperature difference of 1.6 ^{0}C was observed for the naturally ventilated polyhouse. CFD analysis of the naturally ventilated polyhouse shows the wind speed variation within and outside the polyhouse. Cultivation practices, crop planning, and operations for the cultivation in polyhouse are explained in this report. Techno-Economics of the bamboo polyhouse computes the payback period as three years. The ALCC (Annualised Life Cycle Cost) for treated bamboo polyhouse is 18,460 Rs (for 128sqm area), which is Rs. 10,000 less than the quotation received for GI polyhouse.

***Keywords** – Nutri-Garden, Bamboo-polyhouse, structural analysis, ETAB, entrepreneurship model, CFD, dietary diversity*

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ABBREVIATIONS

WHO	World health organization
MDD	Minimum Dietary Diversity
IYCF	Infant and young child feeding
ICDS	Integrated Child Development Services
MMF	Minimum Meal Frequency
NRHM	National Rural Health Mission
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
NFHS	National Family Health survey
MDM	Mid-Day-Meal
ENT	Entrepreneurship
Hb	Hemoglobin
PE	Polyethene
LPP	Linear Programming Problem
SW, WW	South wall, West wall of the polyhouse
UNICEF	United Nations International Children's Emergency Fund
BAIF	Bhartiya Agro Industries Foundation
IS	Indian Standards
CFD	Computational Fluid Dynamics
G-Fab	Geomembrane Fabric
GI	Galvanised Iron
sqm	Square meter
NHB	National Horticulture Board
CFNS	Coalition for Food and Nutrition Security

Chapter 1

INTRODUCTION

1.1 Background

Good nutrition is a human right, a basic need, and is fundamental to health and well-being (WHO, 2019). The well-being of citizens plays an important role in the development of a nation. Lack of basic nutrition causes Malnutrition, which can be defined as *deficiencies, excesses, or imbalance in a person's intake of Energy and/or Nutrients* (WHO). Malnutrition can be seen through symptoms like physical and mental exhaustion, low weight in relation to height (wasting), shortness for age (stunted), diminished skin folds, exaggerated skeletal contours, loss of elasticity of skin (Jitendra Narayan et al., 2018). Young children and lactating and pregnant women are more vulnerable to malnutrition, especially in developing countries like India.

Dietary diversity, consumption patterns, and socioeconomic status are also the major factors affecting malnutrition (Avijit Debnath et al., 2014). Bhavani Shankar et al., (2017) tried to rank the factors affecting malnutrition in tribal India using the non-parametric approach of the regression tree model and founds that breastfeeding is a significant factor, followed by wealth index, antenatal care, maternal malnutrition, and urbanization. Dietary diversity is an essential factor that is also an indirect cause of malnutrition through factors like wealth index, socio-economic status, caste, and gender. In India, only 21% of children receive minimum dietary diversity (CNNS, 2019).

Nutrition Garden is the concept to grow vegetables in the backyard, which will help in increasing the dietary diversity of the household. Even the concept is not new, financial help and training are needed to grow the vegetables sustainably. Different CSR activities, government initiatives, and NGOs are working on developing the Nutri-Garden models for household level, community level, and schools.

Integrated Child Development Scheme (ICDS) provides education and other facilities related to nutrition to pregnant and lactating women through frontline workers. Still, there is a very low proportion of the women receiving nutrition and health-related education from Anganwadi Workers as per the analysis of the District Level Household Survey (DLHS-3). Interventions against malnutrition are being done through various schemes, but we need to find a way to tackle malnutrition through convergence among India's government schemes. A similar guideline letter from the Ministry of Rural Development (MoRD, 2020) shows the scope for developing Nutri-Gardens through MGNREGA. The Nutri-Garden is a small space near the household to grow nutritious vegetables and fruits. The role of MGNREGA will be in helping the beneficiaries building a Nutri-garden individually or at the community level. This guideline report tells in detail about the intervention's beneficiaries, work permitted under the convergence, and some constraints.

The different central and state government directives and their short description is mentioned in Appendix D. Based on these recent directives of state and central government along with the activities of NGOs in the Nutri-Garden / Kitchen Garden; we can say that the development in Nutri-Gardens is a need of an hour to achieve dietary diversity. This thesis reports the Nutri-Garden's demonstration along with Low-Cost Bamboo Polyhouse as an add-on to Nutri-Garden.

1.2 Agriculture and Nutrition Connect in India

Agriculture is responsible for producing grains, vegetables, and fruits, which are then responsible for one’s dietary options. Even the farmer is having access to the field to grow the different crops, though the value of the crop majorly governs his choice. Swarna et al., (2016) performed a district-level analysis to investigate the effect of agriculture GDP, per capita production of Grains on child malnutrition (underweight). To understand the connection between agriculture and nutrition, we can follow the seven pathways given by IFPRI, 2012. These pathways are –

1. Agriculture as a *source of food*
2. Agriculture as a *source of income*
3. The link between agricultural policy and *food prices*
4. Income derived from agriculture and *how it is actually spent*
5. Women’s *socioeconomic status* and their ability to influence household decision-making and intrahousehold allocations of food, health, and care
6. Women’s *ability to manage* the care, feeding, and health of young children
7. Women’s *own nutritional status*

The framework shown in the following figure shows how national nutrition outcomes are dependent on the parameters at different levels and their interconnections.

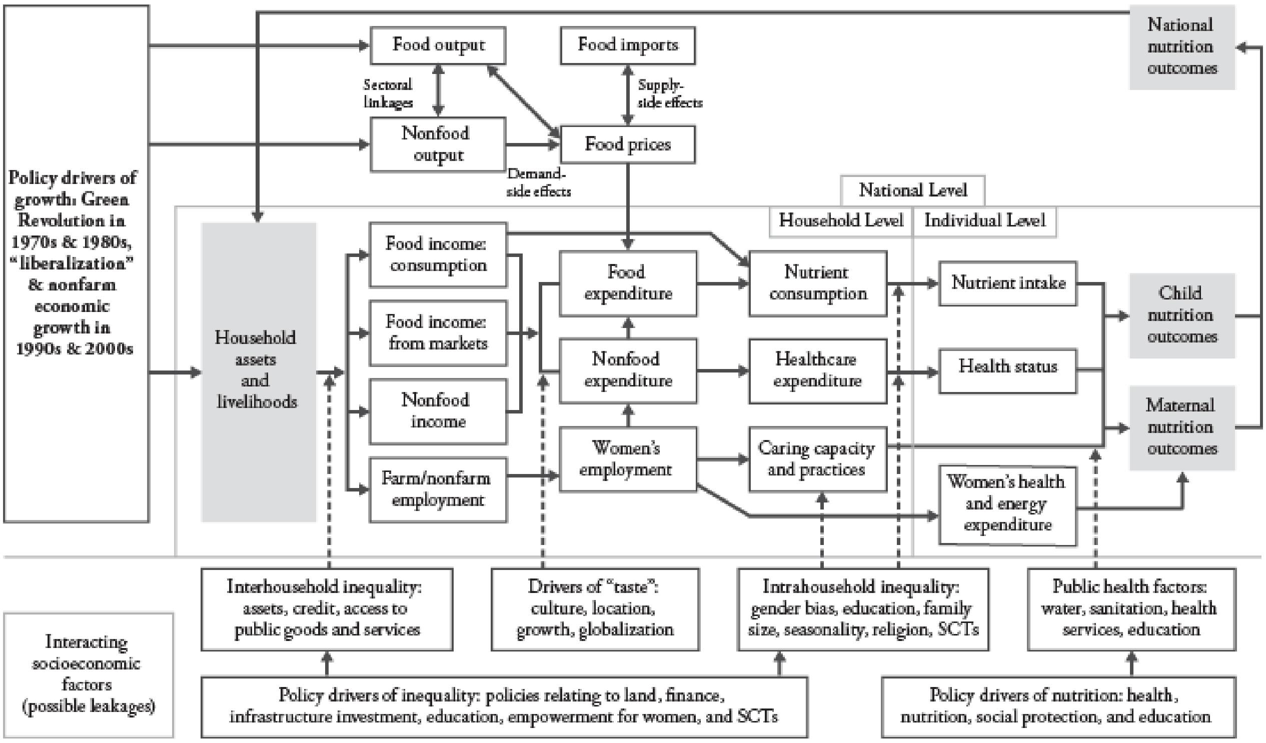


Figure 1. 1: Mapping the agriculture and Nutrition Disconnect (Stuart et al., 2012)

Suppose we decide to make an intervention that will increase nutritional consumption at the individual level and help achieve the National Nutritional outcome. In that case, the intervention should be reliable to give its benefits to the lowest possible level, i.e., individual level. Here comes the role of dietary diversification using Nutrition Gardens at the household level, which can have a reliable nutritional impact on individuals of the family. The above figure also indicates the income and its expenditure; here, we can see the family's spending on food and non-food items, and there are drivers like – taste, culture, location, growth, and globalization that decide the expenditure of the income.

Nutrition Gardens plays an important role in the inclusion of a variety of fruits and vegetables in a diet. Here the expenditure on the nutrition gardens can be increased to get excess produce, and this excess produce is then can be shared or sold in the market. Another possible way of connecting this excess produce to the Mid-Day-Meal program through centralized kitchens will help in adding more chemical-free nutritious vegetables to the meals. This project demonstrates the Nutri-garden with a low-cost bamboo polyhouse as an add-on and its connection to the centralized kitchen.

1.3 Rationale behind the project

Key issues related to malnutrition status found from the NFHS data –

- Only 1/3 of the children from India of age group 6 – 24 months are meeting the Minimum Meal Frequency (MMF)
- Less than ¼ of the children from India are meeting the Minimum Dietary Diversity (MDD)
- Only 9.6% of the children of age group 6-24 months from India receive an adequate diet
- Average 42.7 % of children received semi-solid food with breastmilk, which is declined from 53% in 2006

The requirement of nutritious vegetables and fruits in the Mid-Day-Meal scheme can be fulfilled with the help of surplus from Nutri-Gardens.

The current requirement/ demand of the Centralized kitchen is delivered from the APMCs, which are away from the centralized kitchen site.

The Nutri-gardens can provide household nutrition security as well as the supply of the vegetables to the nearby centralized kitchen.

1.4 Organization of the report

Chapter 1: Presents the background, agriculture and nutrition pathways, framework of the agriculture and nutrition for India

Chapter 2: This chapter covers the research design, methods used, a broad societal concern, research objectives, research questions

Chapter 3: this chapter covers malnutrition and its relation with agriculture

Chapter 4: covers the concept of Nutri-garden and the possibility to scale up the models. This chapter answers the research questions related to – "what is Nutri-Garden and what are the ways to scale up the Nutri-Gardens?"

Chapter 5: reports the findings from the field visit, telephonic interviews, and secondary data related to the status of Nutri-Gardens in India. This chapter answers the research questions related to – "what is the status of Nutri-Gardens in the study area as well as in India?" also explains the ENT model of Nutri-Garden

Chapter 6: covers the introduction towards bamboo structures and the design of the bamboo polyhouse

Chapter 7: covers the analysis of the bamboo polyhouse against different loading conditions

Chapter 8: reports the minute details in the construction of bamboo polyhouse

Chapter 9: provides the analysis of the spatial and temporal variation in temperature & humidity of naturally ventilated polyhouse. This chapter also includes the wind load measurements at different locations

Chapter 10: covers the CFD analysis for the bamboo polyhouse in Ansys. This shows the profile of wind flow inside the polyhouse

Chapter 11: explains the cultivation under polyhouse, including activities and operations required in polyhouse

Chapter 12: explains the techno-economic of the bamboo polyhouse

Chapter 13: concludes the project with limitations and future scope

Chapter 2

RESEARCH DESIGN

This chapter starts with the conceptual framework of the project, followed by a detailed research strategy. The research design also covers the objectives, research questions, methods, and methodology used in the project.

2.1 Conceptual Framework of the Project

This project started with understanding the problem of malnutrition and then understanding the factors affecting malnutrition. Literature survey shows that dietary diversity is one of the significant factors affecting malnutrition. After understanding different strategies to increase dietary diversity, we are attempting to demonstrate the nutrition-garden through the following framework –

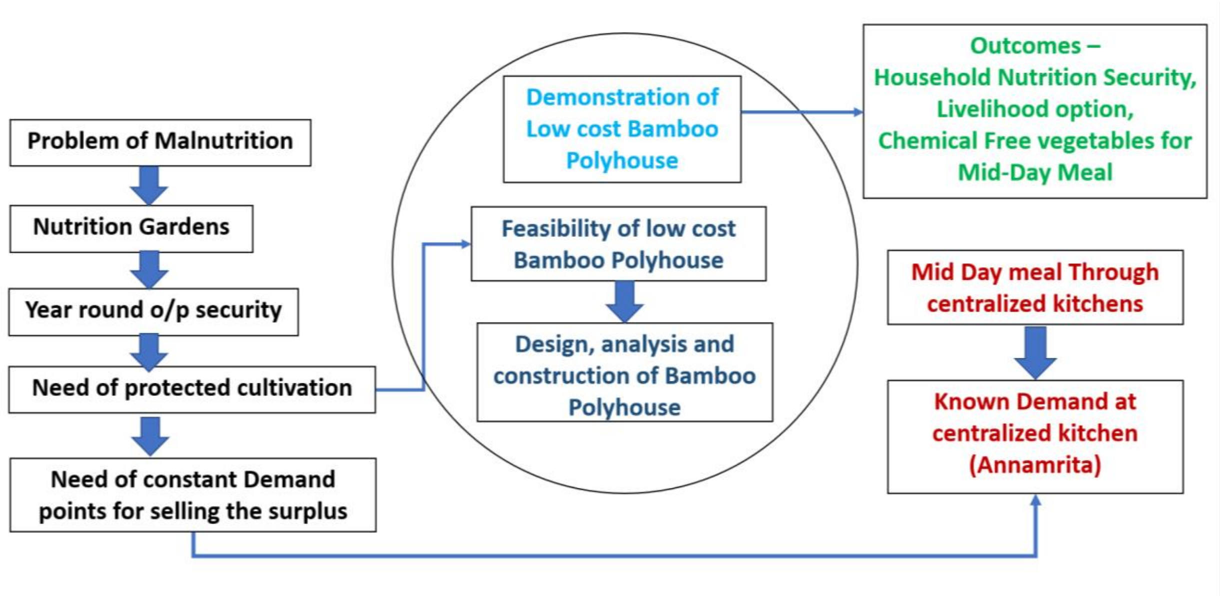


Figure 2. 1: Conceptual Framework of the project

The above figure indicates the scaling-up strategy for Nutri-Garden through a low-cost bamboo polyhouse. The problem of malnutrition can be addressed by achieving MDD and MMF; this requires a local and sustainable solution; here, the concept of Nutri-Garden comes in, which helps in increasing dietary diversity by growing fruits and vegetables in the backyard. The above framework gives a brief idea about the project. The following sections of this chapter will indicate a detailed research strategy.

2.2 Research Design

The severity of malnutrition in India is found more in rural areas than in urban (NFHS, 2015). It is also noticed that rural India is having less wealth index, poor socioeconomic status, less literacy among the female, less food security (Avijit Debnath et al., 2014). This brings us to frame our broad societal concern as –

> Children and women from remote rural India do not meet Minimum Meal Frequency (MMF) and Minimum Dietary Diversity (MDD)

After defining the broad societal concern, the domain of study was fixed on Nutri-Garden. To work on the above BSC following **objectives** were set –

- To design and demonstrate the entrepreneurship model of Nutri-Garden
    - To understand the constraints in the current Nutri-Gardens
    - To design, analyze and develop a low-cost bamboo polyhouse as an add-on to Nutri-Garden
    - To identify the constant/known demand sites to sell the surplus
    - To perform a reality check on marketable surplus and revenue from that
    - To analyze the quantitative data obtained from a demonstration of the Nutri-Garden with bamboo polyhouse as an add-on

To achieve the objectives of the project, the **research questions and sub research questions** can be framed in the following way –

- What is the current status of the nutrition garden in the area of study?
    - What are the constraints faced by Nutri-Garden Growers?
    - What are the coping strategies that people are using against the constraint faced?
    - What is the information source for these coping strategies?
- What is the possible solution against the constraints faced by Nutri-Garden growers?
    - What are the available solutions against the constraints faced?
    - Which of the possible solutions is feasible and sustainable for a particular area?
    - What is the technical, economic, and social feasibility of the solution in the study area?
    - What are the risks involved in the proposed solution?

- Is the solution capable of giving expected surplus along with year-round nutrition security of the household?

- What are the ways to develop a proposed solution?
    - What is the best design of the solution?
    - How to build the proposed solution on the field?
    - What are ways to find a suitable person as an entrepreneur?
    - What are the ways to train the local farmer as an entrepreneur?
- What are the ways to test the performance of the solution before construction?
    - Is the proposed structure safe against different loading conditions?
    - How is the performance of the structure for ventilation?
- Is the proposed solution scalable and sustainable?
    - What are the techno-economical details of the solutions?
    - What are the skills required to develop this solution?

The project is of two phases; in the 1st phase, we have performed a literature survey, preliminary interviews of the Nutri-garden growers. From the analysis of the data collected from interviews, we found that 1) Heavy Rainfall in monsoon and 2) water scarcity in summer are two major constraints faced by the Nutri-Garden growers from Jawhar block. **The methodology** used for the 2nd phase of the project is shown in figure 2.2. After finding the constraints faced by the Nutri-Garden growers, we found the possible solution of the protected cultivation using a low-cost bamboo-polyhouse. After that, we refined our objectives, then performed a Focused group discussion at a centralized kitchen (Annamrita) at Wada. This FGD meet helped in establishing a connection among IIT Bombay, BAIF, and Annamrita stakeholders of the project. After this, to check the feasibility of the fabricator's bamboo structure, we conducted a field visit to Nashik. We observed the bamboo structures, joining methods, foundation, and bamboo structure performance after one year of age. Based on the experience in working on bamboo structures, we selected the fabricator.

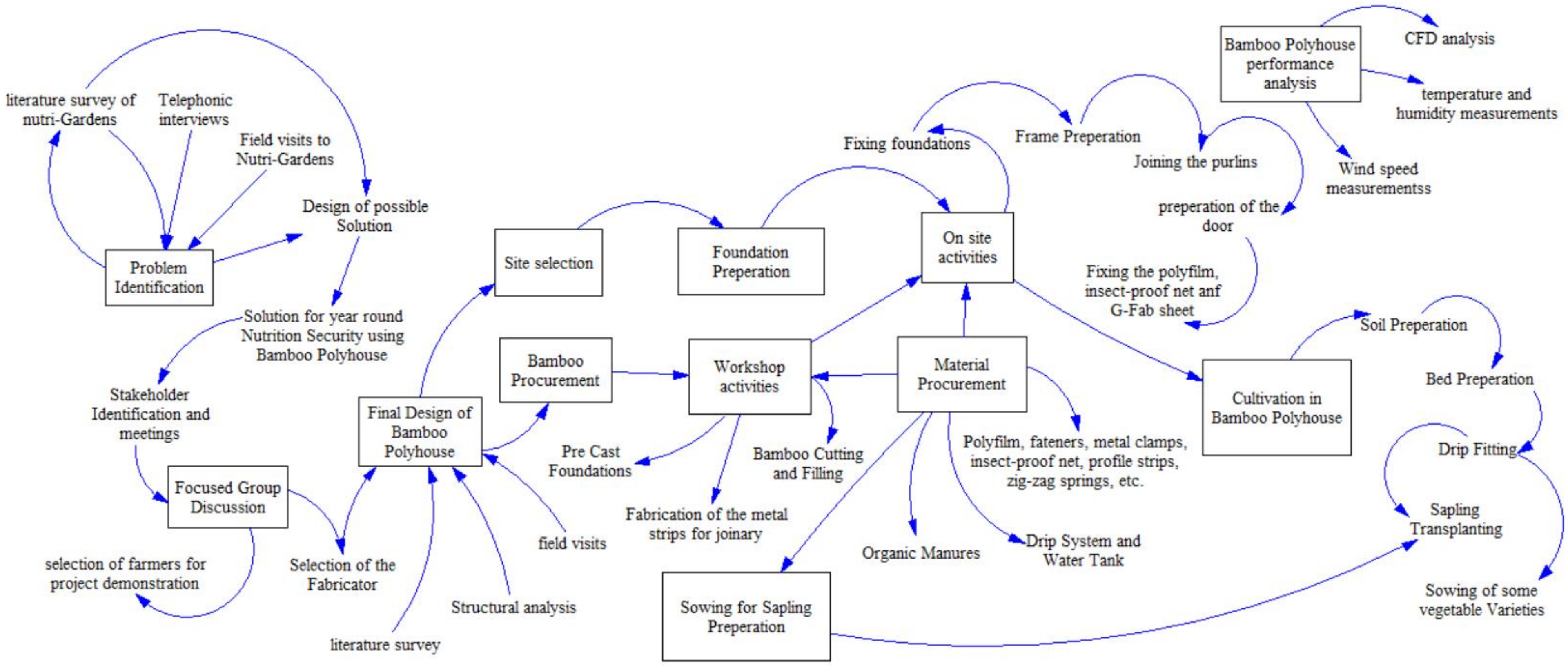


Figure 2. 2: Framework and activities covered in the Project

The above figure 2.2 visualizes the different activities involved in the project. Starting from problem definition to analysis of the bamboo polyhouse performance.

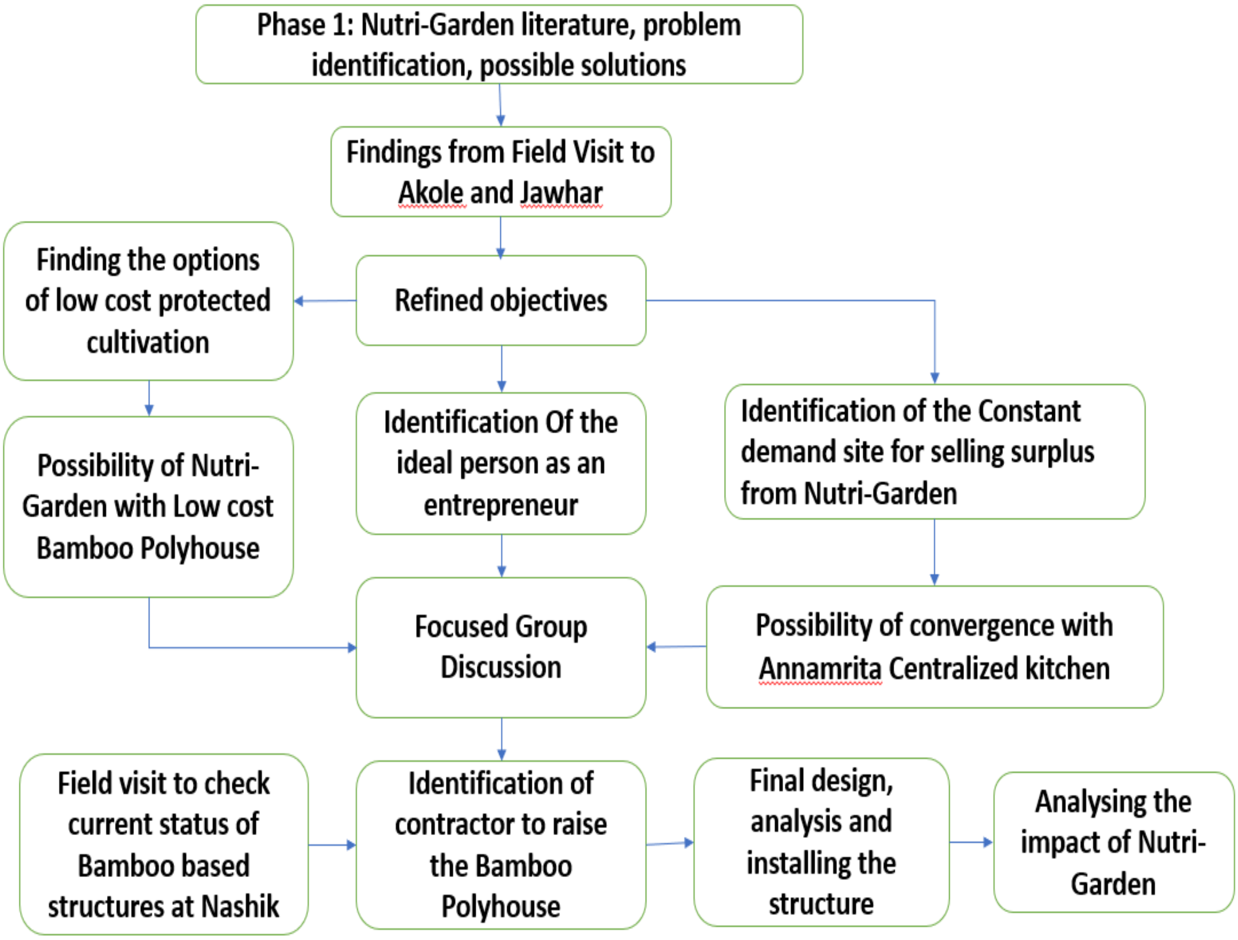


Figure 2. 3: Methodology Chart

2.3 Methods used in the Project

In this section, we will cover the methods used in the project at different stages. This includes the tools and techniques used for data collection, design, and analysis

2.3.1 Data Collection

To understand the current status of the Nutri-Gardens from the Akole and Jawhar block of Maharashtra, we have performed telephonic interviews and site visits. Ten participants from the Akole block and ten participants from the Jawhar block were selected for telephonic interviews based on the mobile network's availability and the relation of the farmer with the BAIF. While choosing the participants, we tried to cover maximum villages, i.e., nine villages for Akole and eight villages for Jawhar. After telephonic interviews, we conducted field visits to five Nutri-garden sites from five villages of Akole block and 5 Nutri-Garden sites from three villages of Jawhar block.

The sampling method to select the block (Jawhar and Akole) is **Purposive sampling**. The sampling method to select the participants is **Convenience sampling.** After the selection of the participants, the interviews were conducted based on the **structured questionnaire.** While doing data analysis, the constraints faced by Nutri-Garden growers were ranked using Garett's Ranking Technique.

Along with primary data with the help from CFNS, we collected the information related to the Nutri-Garden interventions done by many Government and Non-Government organizations in India in the form of a compendium. We considered this as secondary data for analysis.

2.3.2 Design and analysis of the Bamboo Polyhouse

To analyze the bamboo structure for the environmental conditions at proposed sites (Jawhar and Vikramgad), we have performed the analysis by using Indian Standard code – IS 875 for wind load calculations. Material selection for the polyhouse is made based on the hilly vs. non-hilly region-specific approach given by NHB (National Horticulture Board), 2012. The standards for the orientation are also taken from the NHB, (2012) guidelines for polyhouse.

The structural analysis is done using ETAB software, and this can be performed framewise and shellwise loading analysis. Structural properties of the bamboo (Dendrocalamus stocksii) were obtained from the literature survey. As many properties were not available for Dendrocalamus stocksii the Indian Standards code for bamboo (IS 15912, 2018) was used for getting the properties of a similar variety of bamboo. IS-15912 code also helped in designing the joints of Bamboo-Polyhouse. After checking the structural stability, we performed the site visit to check whether the plot is suitable for raising the polyhouse or not? The orientation (North-South), water availability, slope of the land, height from sea level was recorded for analysis.

2.3.3 Data collection to check the performance of the polyhouse

Temperature, humidity, and wind velocity were measured using HTC-1 hygrometer and Vane type anemometer. For the prediction of wind flow within the polyhouse, the CFD-Ansys was used. The farmer records the other performance-related data on irrigation water supply, organic manure preparation + supply, and daily observations.

Chapter 3

NUTRI-GARDENS AND POSSIBILITY TO SCALE UP THE MODELS

3.1 Nutri-Garden and Scale-Up options

A nutrition garden is nothing but a backyard garden where one can grow nutritious vegetables and fruits. This idea of growing vegetables in the backyard is now getting scaled up to have the various food groups in diet and having a livelihood option by selling the surplus. Figure 3.1 shows the possible vegetables grown in Nutri-Garden and the add-ons like poultry, fishery, mushroom farming, and goat rearing.

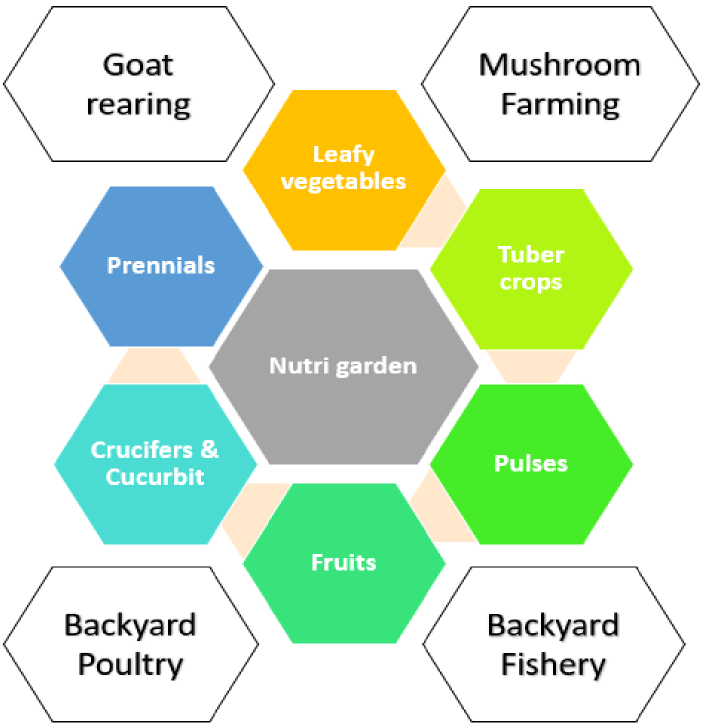


Figure 3. 1: Components in nutrition garden and possible add-ons

To develop an open field Nutri-Garden, we need land. The size of land depends upon the number of beneficiaries from that Nutri-garden. Guiltiness by the Odisha government prepared a type of model based on the number of beneficiaries. These are listed as follows –

Table 3. 1: Types of Nutri-Garden Model based on the number of beneficiaries (Odisha Gov, 2019)

Model type	Area	Output for
1 cent	435.6 sq.ft.	3 people (2A+1C)
2 cent	871.2 sq.ft.	5 people (3A+2C)
3 cent	1306.8 sq.ft.	7 people (4A+3C)
4 cent	1742.4 sq.ft.	9 people (5A+4C)
5 cent	2178.0 sq.ft.	11 people (6A+5C)

(in the above table: A – Adult, C- Children)

After understanding the area required for Nutri-Garden, it is necessary to understand the practices needed for chemical-free agriculture, traditional seeds, etc. Based on the interventions done by various organizations in promoting Nutri-Gardens, we have attempted to standardize the Nutri-Gardens for multiple levels and its scope. Here the level shows the food groups (at level 1 – vegetarian, level 2 – vegetarian + poultry, level 3 – vegetarian + poultry + other). Scope of the Nutri-Garden can be defined on the availability of the produce for A – self-consumption, B – Selling the surplus, C- Selling the surplus with value addition.

Table 3. 2: Standardization of the Nutri-Garden Models

<table>
<tr><th colspan="2" rowspan="2">Standardization of Nutri-Garden Model</th><th colspan="3">Levels</th></tr>
<tr><td>1.0 (Vegetarian)</td><td>2.0 (Vegetarian +Poultry)</td><td>3.0 (Vegetarian + Poultry + Other)</td></tr>
<tr><td rowspan="3">Scope</td><td>A (Self Consumption)</td><td>A1</td><td>A2</td><td>A3</td></tr>
<tr><td>B (Selling Surplus)</td><td>B1</td><td>B2</td><td>B3</td></tr>
<tr><td>C (Selling Surplus with value addition)</td><td>C1</td><td>C2</td><td>C3</td></tr>
</table>

Based on this standardization, we have taken the compendium of the interventions done by different organizations from all over India on Nutri-Garden. These compendiums will be published on a web-portal that will help in creating a platform for understanding the different models of the Nutri-Garden for different regions.

3.2 Ways of Nutri-Garden intervention

Through the literature, government and NGO reports on the intervention of Nutri-Garden, it is observed that the following are the ways to implement the Nutri-Garden intervention

1) At the individual level (backyard kitchen gardens)
2) Community-level Kitchen Gardens
3) School or Anganwadi level Nutrition-Gardens

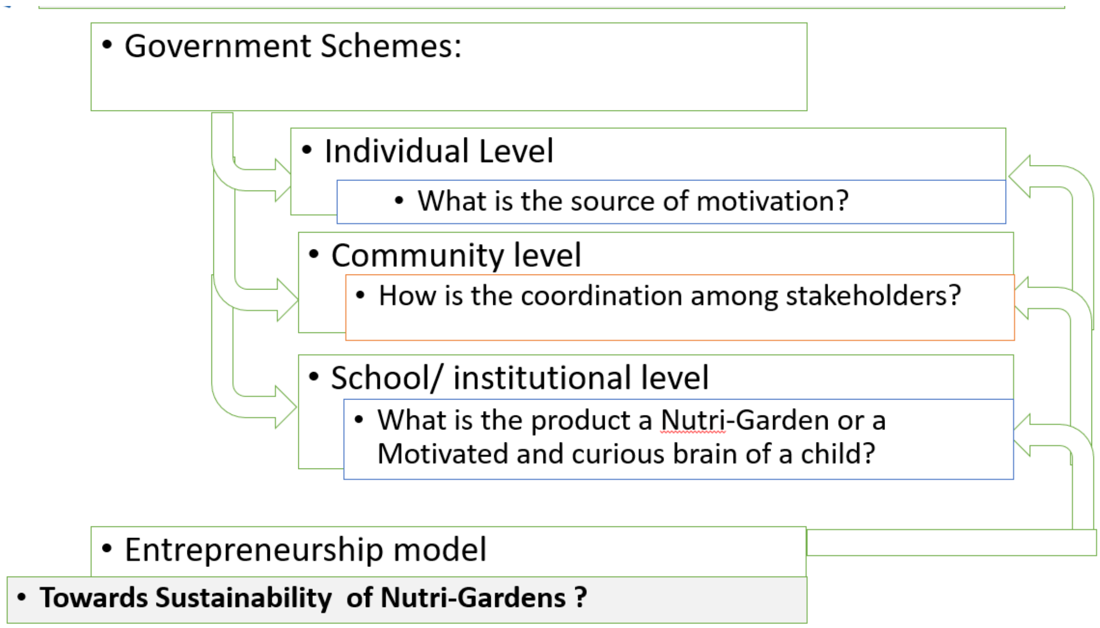


Figure 3. 2: Possible ways of the intervention of Nutri-Garden

Even the Nutri-Garden is promoted through the government scheme or NGO support, the question of sustainability remains. At an individual level, the Nutri-Garden's sustainability depends on the household's motivation to maintain the Nutri-Garden. The community-level Nutri-Garden can give a higher yield, but it depends on the coordination among the stakeholders. The 3rd possible model of Nutrition garden through school or institutional level can be sustained when the children are motivated towards this open science laboratory of Nutri-Garden. Another sustainable Nutrition Garden approach is the Entrepreneurship model. One can grow fruits and vegetables for self-consumption and sell the surplus to the nearest school, Anganwadi, a centralized kitchen providing the mid-day-meal. This will help achieve household nutrition security and provide nutritious chemical-free vegetables to the mid-day meal program.

3.3 Entrepreneurship Model of Nutrition Garden

This project demonstrates the Entrepreneurship model of Nutri-Garden, where the demand site is known (Annamrita centralized kitchen, Wada block, Palghar District). The connection between Nutri-Garden from villages near Annamruta centralized kitchen can be established.

Advantages of the proposed Entrepreneurship model of Nutri-Garden:

- The Households with Nutri-Garden will get an excess income through selling the surplus
- Annamrita trucks can pick up the required vegetables from the farmers' sites while returning from the schools where mid-day-meal tiffins are provided
- The children will be getting fresh, nutritious, and chemical-free vegetables in their meal
- The loss of fruits and vegetables will be minimum (the transportation and inventory losses will be minimized)

Before proposing the entrepreneurship model of Nutri-Garden, we tried to identify the constraints faced by the Nutri-Garden growers from the Jawhar block of the Palghar district.

Chapter 4

CURRENT STATUS OF THE NUTRI-GARDENS

Jawhar is one of the tribal blocks of the Palghar district in Maharashtra. The higher malnutrition status of the Jawhar block needs immediate action for its control. To address malnutrition in Jawhar, BAIF did an intervention of Kitchen Gardens, aiming to provide household food security and dietary diversity. This section includes analysis of the primary data collected from the field visit to the five Kitchen Garden sites from 3 villages of Jawhar block and the study of data collected from telephonic interviews of 10 kitchen garden beneficiaries from 10 villages of Jawhar block. The analysis includes the types of vegetables grown in the kitchen garden, irrigation practices, and farmers' constraints in year-round production security from the kitchen garden.

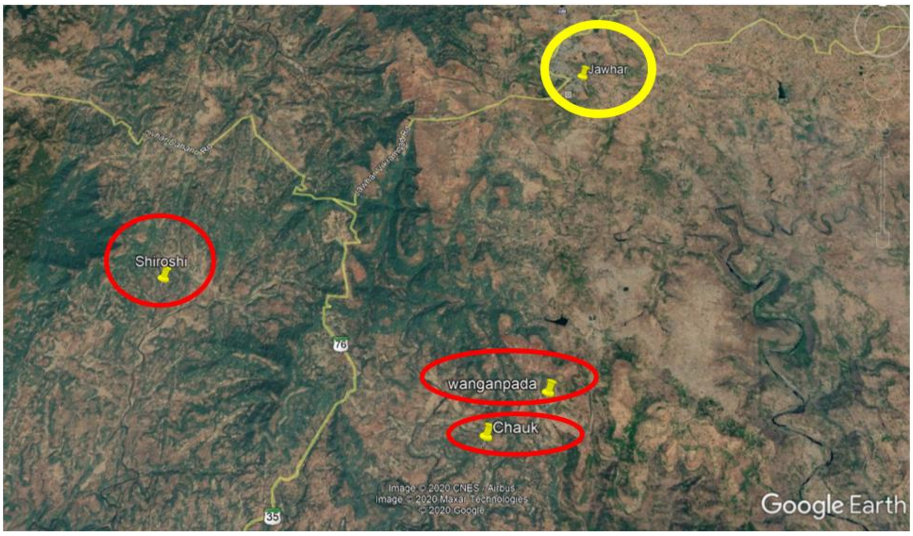


Figure 4. 1: Villages visited during the field visit to Jawhar

During the field visit to Nutri-Gardens from Jawhar block – we have visited five sites from three villages (Shiroshi-2, Wanganpada-2, Chauk-1).

Participants of the telephonic interviews belong from the –

1. KokanPada	2. Wanganpada
3. Valvande	4. ChamilPada
5. Chirecha	6. Pada Chauk
7. Vanvasipada	8. Shiroshi

4.1 Dietary Diversity and Year-round Consumption of different food groups in Jawhar block

We have collected data from current Nutri-Garden growers during the telephonic interviews and field visits regarding their consumption pattern and the source of food items. The data is collected for three seasons – the rainy season, winter, and summer. The data of food source is categorized in terms of consumption of externally purchased food items in kg/month and consumption of self-grown food items in Kg/Month.

The following table 4.1 shows the average of the responses produced from a sample size of 7 families (5 during field visits + 2 telephonic). This table covers the eight food groups; inside these food groups, details about every food item were recorded, and the survey form is shown in appendix F.

Table 4. 1: source of food groups and their consumption in three seasons in (Kg/Month)

	Consumption in Kg/month Rainy Season			Consumption in Kg/month Winter			Consumption in Kg/month Summer		
Food Groups	Externally Purchased	Self-grown	*Total*	Externally Purchased	Self-grown	*Total*	Externally Purchased	Self-grown	*Total*
Rice + Grains		20	*20*		20	*20*		20	*20*
Tubers	6	0	*6*	5	2.5	*7.5*	8	2.5	*10.5*
Vegetables	27	13.4	*40.4*	28	16.9	*44.9*	2	30.9	*32.9*
Fruits	1.5	8.3	*9.8*	1.5	8.3	*9.8*	1.5	28.3	*29.8*
Meat	2	0.25	*2.25*	2	0.25	*2.25*	2	0.25	*2.25*
Fish	2.95	7	*9.95*	1.7	0	*1.7*	1.7	0	*1.7*
Milk	2		*2*	2		*2*	2		*2*
Spices, condiments, beverages	5.8	0.4	*6.2*	5.8	0.4	*6.2*	5.8	0.4	*6.2*
Pulses	1.5	31	*32.5*	1.5	31	*32.5*	1.5	31	*32.5*
Total	**48.75**	**80.35**	**129.1**	**47.5**	**79.35**	**126.85**	**24.5**	**113.35**	**137.85**

From the above table, we can see the milk consumption is deficient in the Jawhar block. Milk is rich in different micronutrients, which include calcium, vitamin B12, B6, B2, phosphorus, potassium, and a small amount of - magnesium, selenium, vitamin D, vitamin A, and zinc.

To understand the change in consumption through an external and self-grown source of food items following graphs are made –

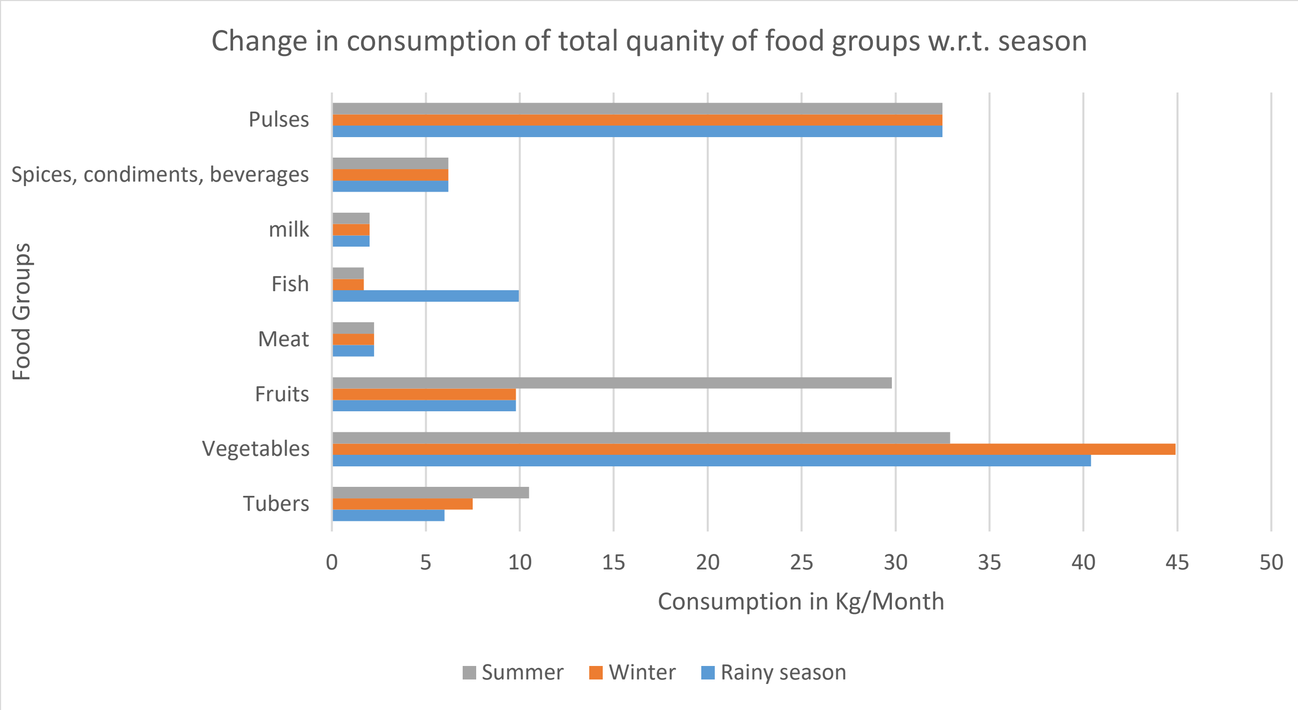


Figure 4. 2: Change in total consumption per month w.r.t. season

From figure 4.2, it is clear that vegetable consumption per month is maximum in winter and minimum in summer. The consumption of tubers is maximum for months of summer.

Figure 4. 3: Change in consumption of externally purchased food groups w.r.t. season

Figure 4.3 shows the change in consumption for different food groups w.r.t. season. We can see that vegetable consumption of externally purchased food items reduced from 28Kg/month to 2kg/month is summer due to the 25Kg/month onions consumed through a self-grown source.

It is also seen that the fruit consumption is highest in the months of summer for self-grown food items. This is due to the interviewed farmers are

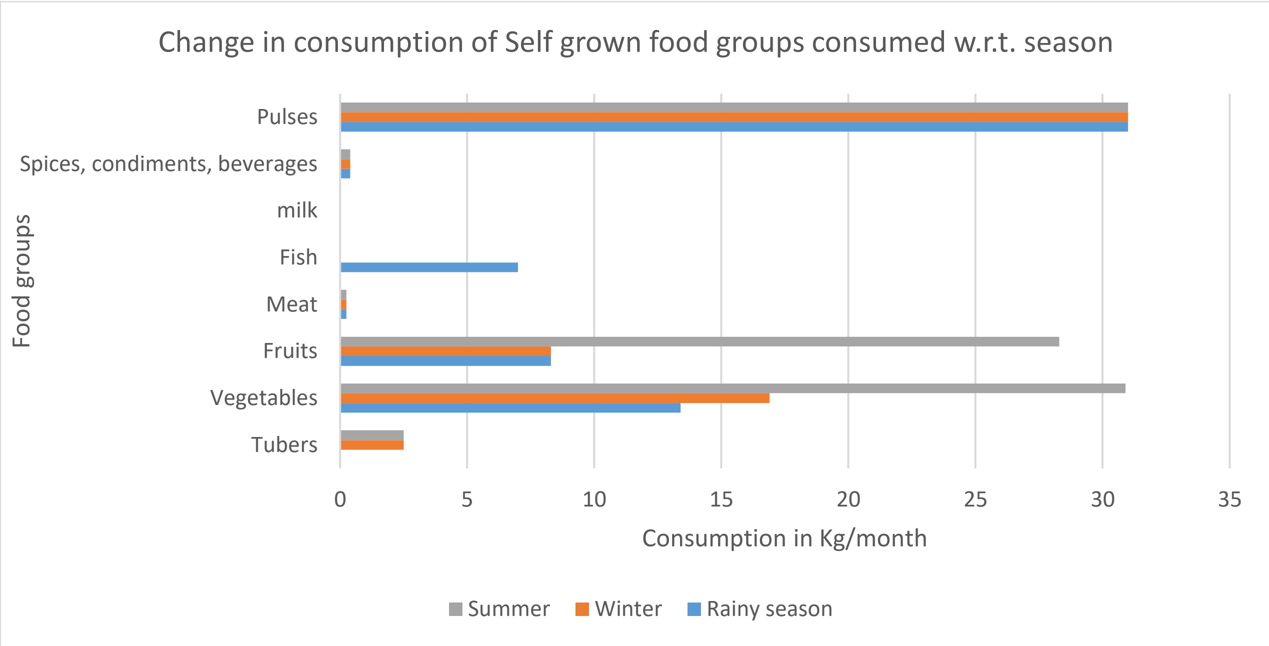


Figure 4. 4: Change in consumption of self-grown food groups w.r.t. season

Fish consumption through the self-grown food group category happens only in the months of the rainy season. This is due to the availability of water and fish in the river during the monsoon.

The detailed analysis for consumption of every food item under the mentioned food groups is shown in Appendix F.

4.2 Constraints Faced by Nutri-Garden Growers from Jawhar block of Palghar

Based on the responses from ten telephonic interviews and five site visits, the Nutri-Garden Growers' common constraints are ranked using Garett's Ranking Technique. The steps in ranking the constraints are as follows –

1. Ranks are given by respondents
2. Rank vs. Constraint Table
3. %position = 100 (rank – 0.5) / total constraints
4. Garett's score for % position from Garett's score table
5. Rank * Score matrix → total score → Average score → assign a rank

After executing the above steps, the following table is showing the rank of the constraints faced by Nutri-Garden growers –

Table 4. 2: Ranking of the Constraints Faced by Nutri-Garden growers from Jawhar block of Palghar

Constraints faced by Nutri-Garden Growers From Jawhar	Average Garett score	Effective rank
Water Scarcity in summer	67.77778	1
Heavy rainfall	55	2
No Protection against animals	51.66667	3
Pest and disease	48.88889	4
Market Availablity for selling the produce	26.66667	5

The first two constraints of water scarcity and excessive rainfall promote the seasonal migration of the farmers in the nearby cities as construction or other daily wage workers. Due to this seasonal migration, cattle belonging to these migrated workers becomes free and creates a 3rd constraint of "No protection against the animals."

4.3 Coping Strategies against the constraints faced

In the Jawhar block, after growing rice in the Kharif season, farmers used to migrate for daily wages in the nearby cities. To address water scarcity in summer, the NGO called BAIF provides the drip irrigation system, helping the farmers make farm ponds, etc. The recent supply chain of Mogra flower created with the help of BAIF helped in reducing the seasonal migration, and farmers started getting the livelihood option.

The problem of protection against wild animals can be solved by making the compounds. BAIF helps in providing the metal wires for fencing, where farmers bring the supporting columns in the form of wood. Few farmers are using Natural fencing by growing the trees from the family of cactus.

Figure 4. 5: Natural Compound of Cactus to the Nutri-Garden

Even the coping strategies for water scarcity and fencing are solved up to some extent; the year-round vegetable production security is not achieved. Here comes the scope for protected cultivation, which can be used for year-round production security. This production security will help in connecting the Nutri-Gardens with a nearby centralized kitchen (Annamrita) for selling the surplus.

4.4 Conclusions from the analysis of the data collected from the field visit and the telephonic interviews:

- The Nutri-Gardens from the Akole is performing better than the Nutri-Gardens from the Jawhar block. The excess produce and the Nutri-Garden income show the gap between the Nutri-Garden performance. 4 out of 5 Nutri-Garden growers can sell the excess produce in the Akole cluster. In comparison, only 2 out of 5 Nutri-Garden growers can sell the excess produce in the Jawhar cluster
- The Nutri-Garden growers from Jawhar block face the following constraints - Water scarcity, Protection from animals (Compound for Nutri-Garden), Excess rainfall in monsoon, Less water holding capacity of the soil, and marketing channel of the excess produce
- No large scale poultry was found in any of the visited sites of Nutri-Garden from Jawhar block
- The add-ons to the Nutri-Garden for additional nutrition source and as an income source are less in the cluster of Jawhar
- The distinguishing feature in terms of food intake is that the farmers from Jawhar eat three times a day while the average frequency of meal is two times a day in Akole block
- As per the respondents, more irrigation is required due to high runoff, less water holding capacity of the soil, and high summer temperature
- Following table 4.2 shows the availability of different vegetables in the kitchen gardens from Jawhar block

Table 4. 3: Seasonal Availability of vegetables in kitchen gardens from Jawhar block

Sr. No.	Vegetables	Seasonal Availability		
		Rainy Season	Winter	Summer
1.	**Tubers** – Alu-kand, Karande, Suran, sweet-potato, Radish	Under cultivation	Consumption starts in winter	
2	Fenugreek, onion, Cluster beans, peas (cultivation after rice crop).		Under Cultivation	Consumption starts at the end of winter
3	Wal (Flat green beans), Karali (Bitter gourd), Bhopala (Bottle gourd), Ridge gourd, Bhendi (Okra)	Consumption starts in the mid-rainy season		
4	Ambadi, and some wild vegetables	Only available in monsoon		

4.5 Understanding the Nutri-Gardens in India

In the above chapter, we have seen the different types of Nutri-Garden models. Different NGOs and government organizations like State Livelihood missions are promoting the Nutri-Gardens. To understand the Nutri-Gardens from different states, we have taken the help of CFNS compendium on Nutri-Garden. This document includes 22 compendiums received from 15 organizations from all over India. In table 3.2, we have seen the standardization of the Nutri-Gardens by assigning the code to it. The following table 4.3 shows the classification of these 22 compendiums based on their scope and level

Table 4. 4: Classification of the Nutri-Garden compendiums (CFNS, 2021)

	1 Fruit/Seeds/ Vegetable	**2 Vegetarian + Poultry**	**3 Vegetarian + Poultry + Other**
A - Only Consumption	6	0	1
B - Selling Surplus	10	2	1
C - Selling Surplus with value addition	1	0	1

The above table shows that most of the Nutri-Gardens in India are meant for vegetables and fruits only. From interviews of the farmers, one constraint shows – keeping the poultry of local variety of chicken (non-hybrid) without the shed makes it difficult to cultivate vegetables, as the poultry birds eat the vegetables at an early stage.

Table 4. 5: Key challenges mentioned by different organizations in implementing Nutri-Garden Intervention (CFNS, 2021)

Sr. No	Challenges in Nutri-Garden program implementation	Region of Intervention	Organization Name
1	Land Unavailability near the house	Bihar, Tamilnadu, Jharkhand	BAIF, CORD, Ekjut
2	The threat of open animals like cows, buffalo, goats, etc.	Bihar, Maharashtra	BAIF
3	Water Scarcity	Maharashtra, Jharkhand	BAIF, Ekjut
4	Verification in Landholding	Maharashtra	BAIF
5	Production & storage of quality seeds	Maharashtra	BAIF
6	Pest, Disease attack	Maharashtra	BAIF
7	lack of continuous engagement;	Jharkhand	Ekjut
Challenges in growing Anganwadi Nutri-Garden			
1	Safety issues for KG after AWCs working hours	Rajasthan	Hindustan Zink Ltd.
2	Lack of feasible spaces & water at AWCs		
3	Uncertainty of survival of fruit plants		

Figure 4.3 shows the locations from India where the interventions of Nutri-Garden are promoted. In India, other states are also having Nutri-Gardens; due to the unavailability of the data, these are not included in the Nutri-Garden compendium developed by CFNS.

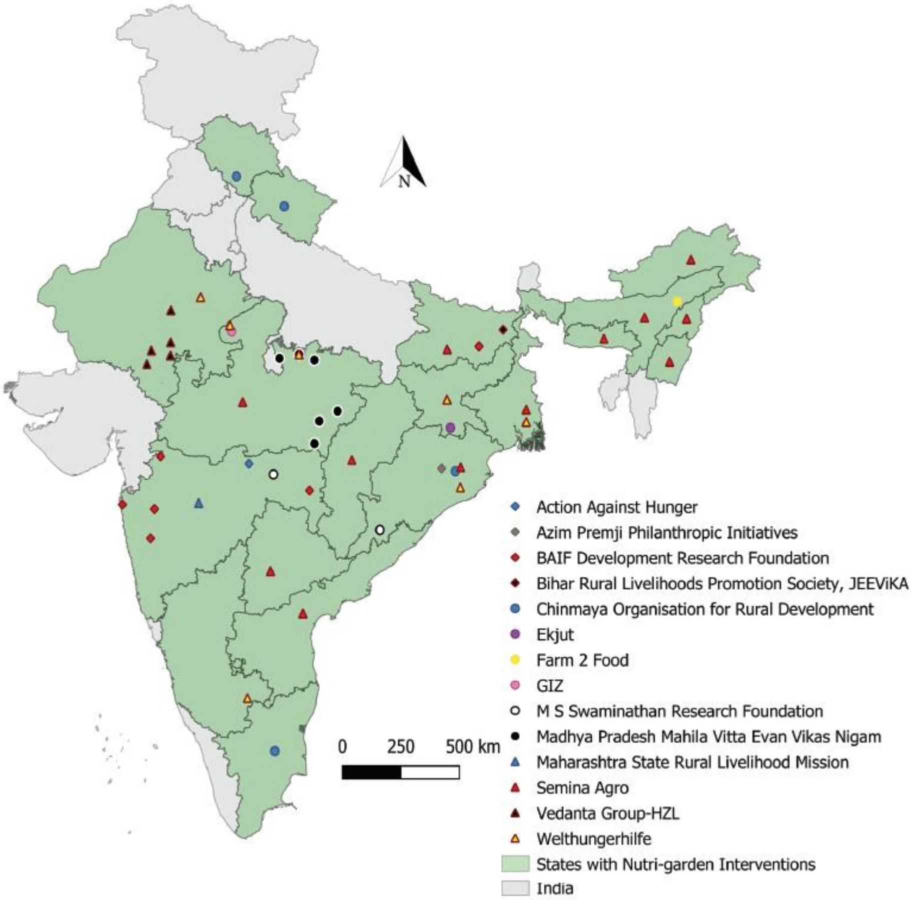


Figure 4. 6: Mapping of Nutri-Garden intervention locations in India (CFNS, 2021)

Table 4.4, showing the different types of challenges faced by the organizations in implementing the Nutri-Gardens. The challenges in growing the Nutri-Garden for Anganwadi are also mentioned by Hindustan Zinc Ltd. organization in a compendium of Nutri-Garden for Rajasthan state. The intervention of Nutri-Garden for a school is developed by the Farm to Food organization from Asam. This success story also tells about the "Financial Bank" developed by the students based on sales of excess produce from school Nutri-Garden. The organizations define Nutri-Garden in terms of source of nutritious food and a laboratory to experiment and understand scientific concepts.

To overcome the challenges mentioned in table 4.4, different kinds of technological interventions can be done. Few of the compendiums of Nutri-Garden show the effective ways of cropping inside the pots, where there is water scarcity. This method can work better against water scarcity but the productivity will go down. To tackle the problem of different pest attacks, farmers are trained through organizations to make organic manure.

This compendium report also explains the fertilizers used in growing the Nutri-Garden. The size and shape of the Nutri-Garden, etc. Some organizations also prepared a layout by defining the positions of the crops and perennial plants, which will help in effective growth of Nutri-Garden.

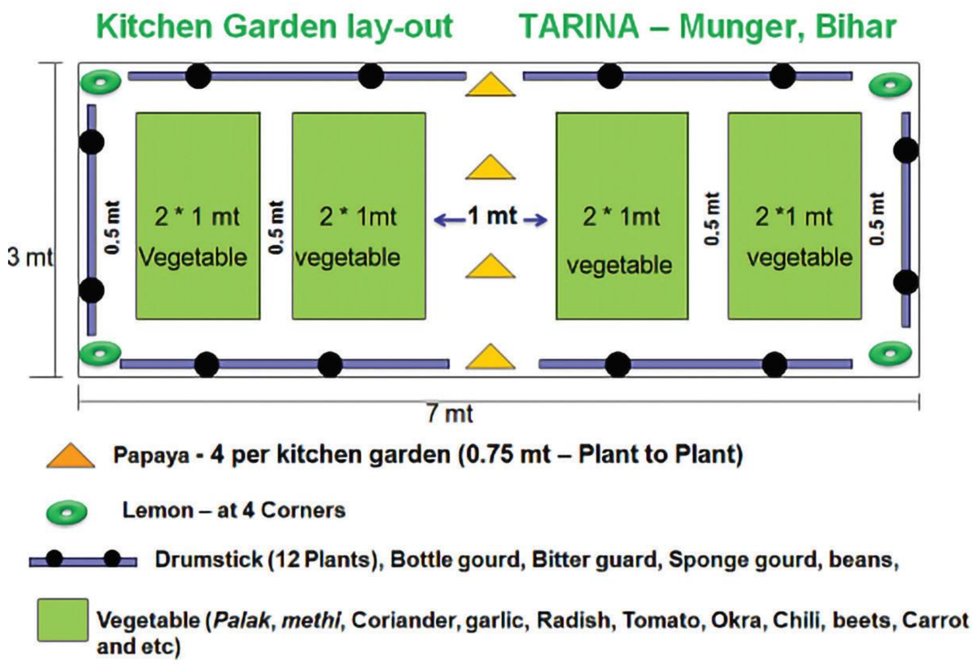


Figure 4. 7: Layout of the Nutri-Garden from Munger, Bihar developed by BAIF (CFNS, 2021)

In figure 4.4, the distance unit 1 mt = 1 meter, and the total area of the model is = 21 sqm = 210sqft. This model is very small-sized; BAIF also mentions the area availability constraints near the household in the Munger block of Bihar.

Chapter 5

ENTREPRENEURSHIP MODEL OF NUTRI-GARDEN IN JAWHAR AND VIKRAMGAD BLOCK OF PALGHAR

This chapter covers the design of the project, which includes connecting the Nutri-Gardens to the centralized kitchen - Annamrita, a possible solution for year-round production security from Nutri-Garden, site selection for the proposed intervention, etc.

After understanding the constraints faced by the Nutri-garden growers from Jawhar block in getting year-round production security, we found the possible solution of the protected cultivation. Here the area in which the model of Nutri-garden needs protected cultivation can be 1000-1200 sq. ft, and the economic feasibility of the conventional GI/ steel polyhouse is not significant for the small structures of this much area. Then we explored the possibility of a low-cost bamboo polyhouse. To select the farmers for demonstrating this model of Nutri-Garden and connect the project stakeholders, we conducted a focused group discussion (FGD) at Annamrita, a centralized kitchen near Wada.

5.1 Focused Group Discussion

The FGD was conducted on 2nd Dec 2020 at Annamrita's centralized kitchen. Along with IIT Bombay, BAIF, and Annamrita project team, 23 farmers and local bamboo workers were present in the FGD. Following are the key findings from the FGD –

- Understanding the constraints faced by Annamrita Centralized kitchen –
  - Annamrita CK mentioned that they did not get constant supply from the farmers when they demonstrated the purchasing from local farmers
  - Even Annamrita kitchen is located near Wada; they need to purchase the vegetables from Vashi APMC, Navi Mumbai
  - This gap in fluctuating supply and known/ constant demand need to be filled
- Identification of the two farmers for demonstration of the entrepreneurship model of Nutri-garden
  - Based on the structured questionnaire and
  - Consultation with BAIF field experts, we identified two farmers for demonstrating the proposed intervention

- All the farmers and local bamboo workers showed an interest in learning the construction of bamboo polyhouse
- Understanding the demand for vegetables at Annamrita CK
    - Vegetable wise demand quantity for a week is given in the following table –

Table 4. 6: Vegetable Requirement at Annamrita centralized kitchen

Sr. No	**Vegetable**	**Weekly Requirement (Quintal/week)**	**Order frequency for a week**
1	Beans	1	1
2	Carrot	160	1
3	Dhaniya Patta	105	1
4	Dudhi (Bottlegourd)	300	2
5	Ginger	64.5	3
6	Kadipatta	25.5	3
7	Mirchi (chili)	39	3
8	Palak (Spinach)	1	1
9	Potato	2235	3
10	Pumpkin	910	3
11	Shimla Mirch (capsicum)	160	1
12	Tomato	1050	3
13	Tondli	1	1
14	Patta Gobi	1	1

- Apart from the above-mentioned vegetables following are the vegetables that are also required at Annamrita CK –

Brinjal, Beet, Cauliflower, Kakdi (cucumber), Green Peas, Gavar (cluster beans), Suran, Sweet Corn, Drumstick, Methi (fenugreek)

- Average weekly demand of the vegetables for a centralized kitchen =
  = 5050 quintals/week = 842 quintal/day

The two farmers selected for demonstration of the bamboo polyhouse based nutrition garden are from Jawhar and Vikramgad blocks of Palghar. And the Annamrita centralized kitchen is located in the Wada block of the Palghar district.

Methodology to select the farmers is mentioned as follows –

- Identification of the important factors to be considered for the selection of the farmer
- Defining the decision tree for farmer selection
- Quantification method to convert qualitative, fuzzy responses in a quantitative data
- Assigning the weights to the factors based on their importance
- Calculating the weighted sum of the scores corresponding to different factors
- Making a decision based on analysis

Figure 5.1 explains the steps in the decision tree used to select the farmer to demonstrate the protected cultivation model of Nutri-Garden. In the second last step of the decision tree, we need to compute the weighted average sum of the scores corresponding to factors considered for selecting the farmer.

Table 5. 1: Factors used in weighted sum to make the final decision of farmer selection

Sr. No.	Factor	Response Type and Range	Normalization	Assigned Weight
1	Water Availability	1 (less water year-round) to 9 (Satisfactory water available in summer)	Mini-max	60%
2	Experience in Growing vegetables	0 to 5 yrs 5 to 10 yrs >10 years	Mini-Max (0=minimum, 10 = Maximum)	20%
3	Experience in Marketing the	0 to 5 yrs 5 to 10 yrs >10 years	Mini-Max (0=minimum, 10 = Maximum)	20%

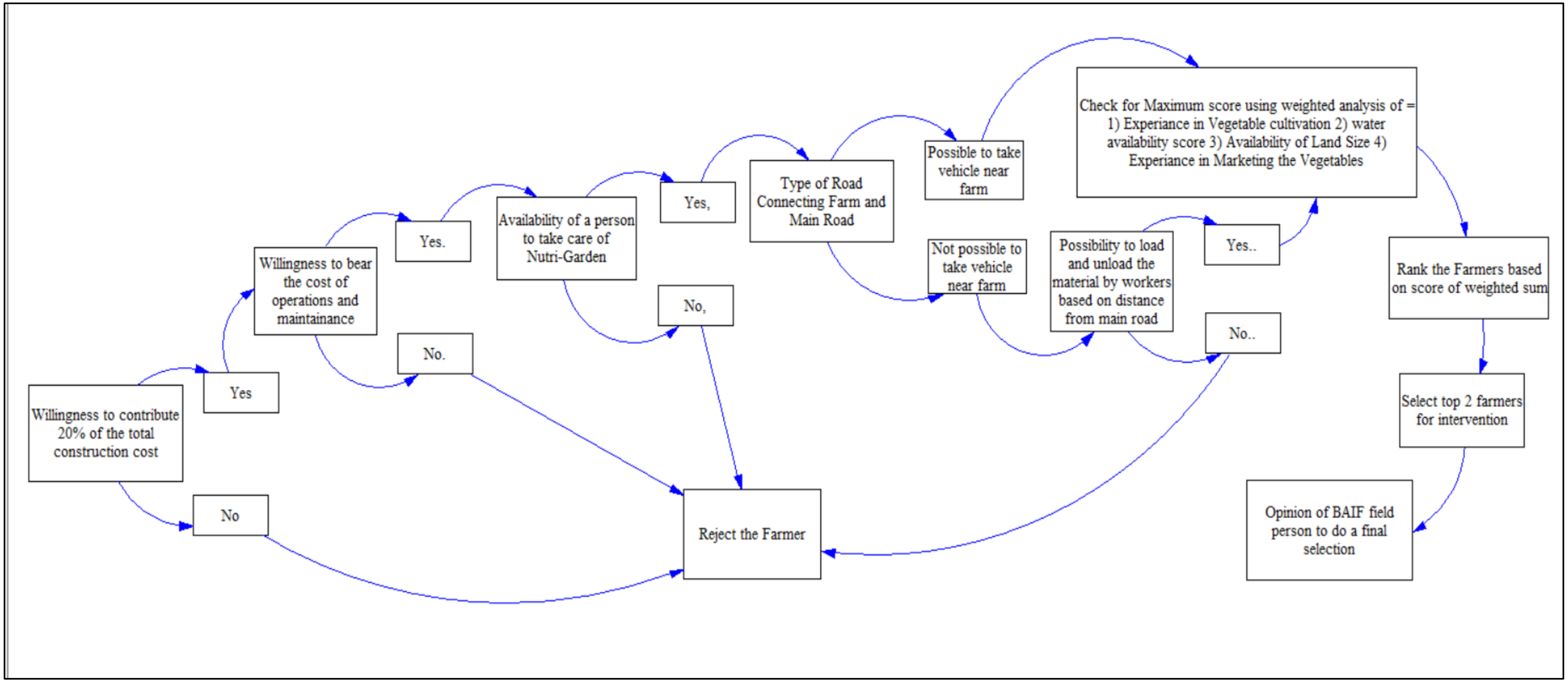


Figure 5. 1: Decision Tree used to select the farmer to demonstrate the ENT model of Nutri-Garden

To normalize the data in the range of 0 to 1, we have used the Mini-Max method, which works as =

$$Normalized\ x = \frac{x - min}{max - min} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots (5.1)$$

Based on this methodology, we selected two farmers—one from the Jawhar block and one from the Vikramgad block of Palghar district.

5.2 Rationale behind the selection of study area

The selected farmers for demonstration of the intervention are from the –

1) Ramkhind hamlet, Pathardi Village, Jawhar, Palghar
2) Patlipada hamlet, Balapur Village, Vikramgad, Palghar

Both the hamlets are in remote tribal areas. We have found from the NFHS-4 survey that the tribal population is more vulnerable to malnutrition as shown in figure 5.1 (NFHS 4, 2015-16).

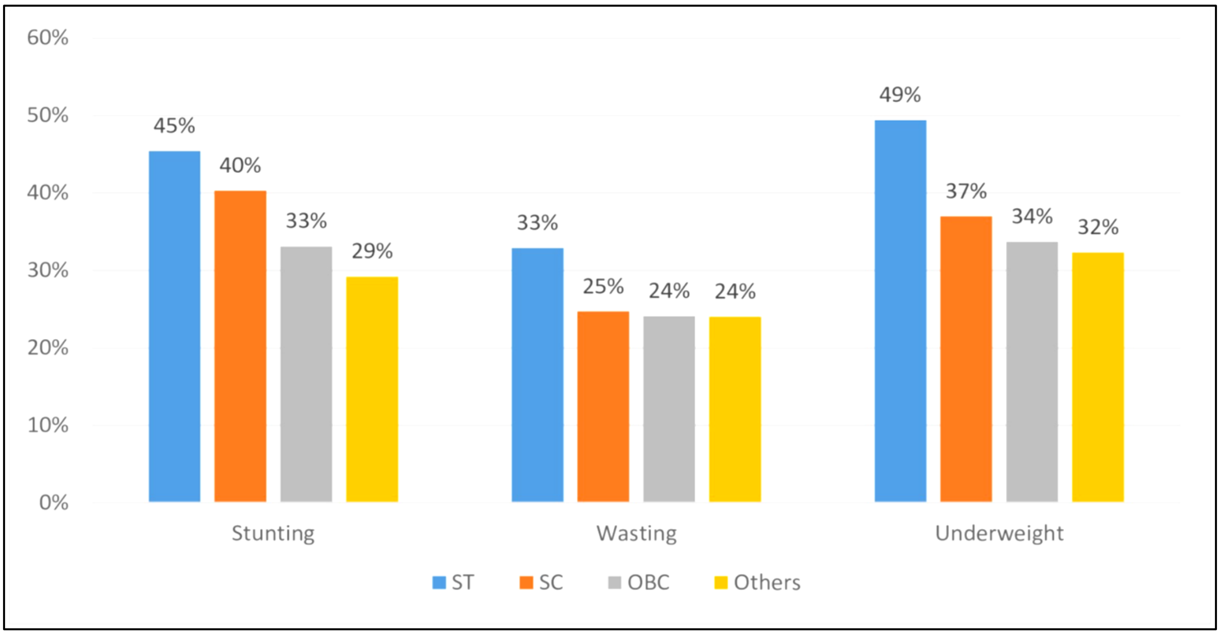


Figure 5. 2: Caste-Wise malnutrition Status of the children under five years of age

Both the blocks – Jawhar and Vikramgad show higher rates of malnutrition. Saumitra and Sarika, (2019) performed a study on malnutrition among the children from the Vikramgad block of Palghar. They found that the average percentage of the children stunted is near to 60%, and underweight % is near to 54%, as shown in Figure 5.2 -

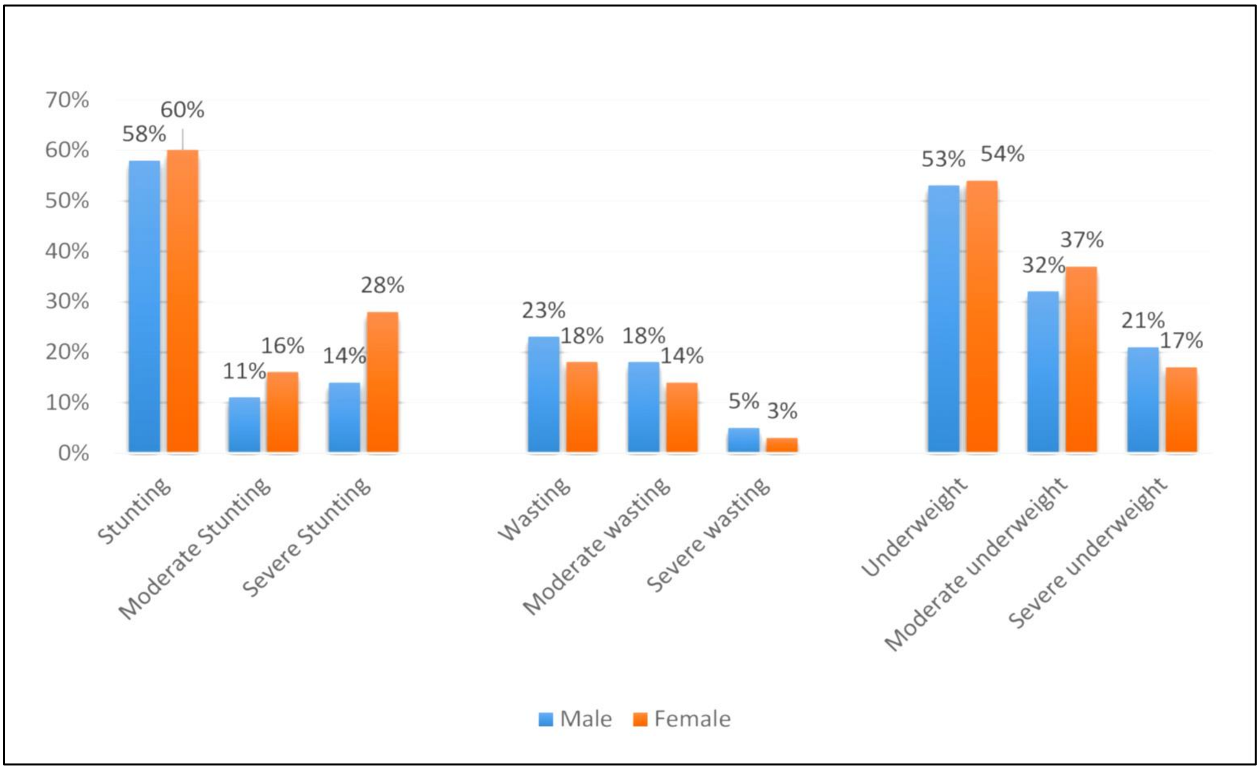


Figure 5. 3: Percentage of the malnourished children below five years of age

Variation in the height of the location from sea level –

1) Ramkhind from Jawhar is 293m above the sea level
2) Patlipada from Vikramgad is 60m above the sea level

This variation will be considered in structurally analyzing the bamboo polyhouse model.

5.3 System dynamics model for ENT model of Nutri-Garden

After knowing the vegetable demand at Centralized Kitchen, we can estimate the number of households that should be connected to provide this much output. Here we know that the weekly demand of the centralized kitchen is 5050 quintals/week. Assuming a Nutri-Garden with bamboo polyhouse is having the productivity of 10-15 kg/sq.m (15.5kg/sqm for tomato, 15 kg/sqm for capsicum, 11 kg/sqm for cucumber) (source – agrifarming.in). Based on the harvesting period of 10 to 15 days for above crops the maximum possible quantity supplied by each farmer through bamboo polyhouse = 2 quintals per day for the period of harvesting. When we average out this harvesting period for a complete life cycle of 80 days the average produce can range between 15 to 20 kg/day. In addition to the protected cultivation from 1000 sq. ft. We can add the open field kitchen garden produce around – 10kg/day/3000sq.ft. Total assumed harvest of 25 to 30 kg/day from one farmer, then to fulfil demand of around 842 quintals/ day we will be required to connect with 2800 to 3000 farmers. Assuming that 50 households in a village will get associated with Annamrita, then 60 villages need to be connected. The following SD model can be simulated based on the productivity of the Nutri-Garden, sales to Annamrita CK, number of farmers in connect with Annamrita, and conversion rate through which possible farmers who can be associated with Annamrita are getting connected.

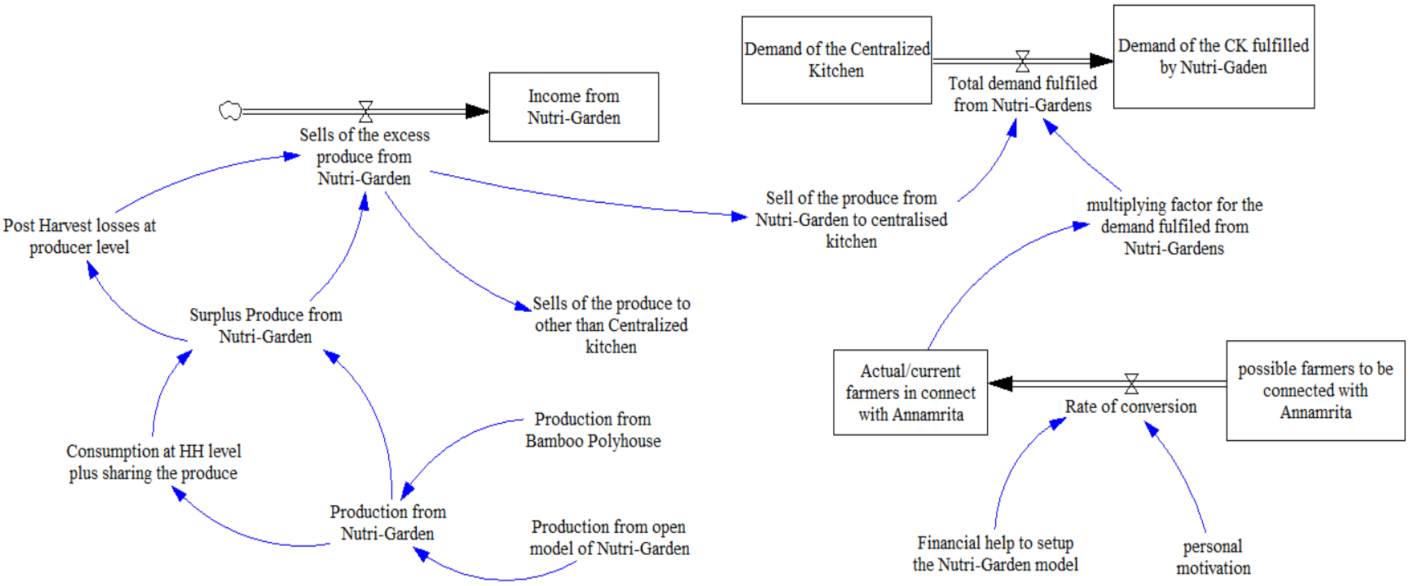


Figure 5. 4: System dynamics model for ENT model of Nutri-Garden

From the FGD, it was clear that the transport of the Annamrita runs in all three blocks – Wada, Jawhar, and Vikramgad. This indicates there will not be any constraints in receiving the vegetables from the route of Annamrita transportation.

To analyze the above model following assumptions were made =

- Production from Bamboo-Polyhouse of 100 sqm is 100 kg/month
- Production from openly cultivated 100 sqm Nutri-Garden is 25kg/month
- The factor of personal motivation = 0.2, assuming 20% of people are motivated to grow the Nutri-Garden ENT model
- Assuming that the - help given by local NGOs is contributing by a factor of 80% in covering the farmers in a rural area
- The total rate of conversion is the multiplication of the Factor of personal motivation and the factor of financial and other help provided by the NGOs

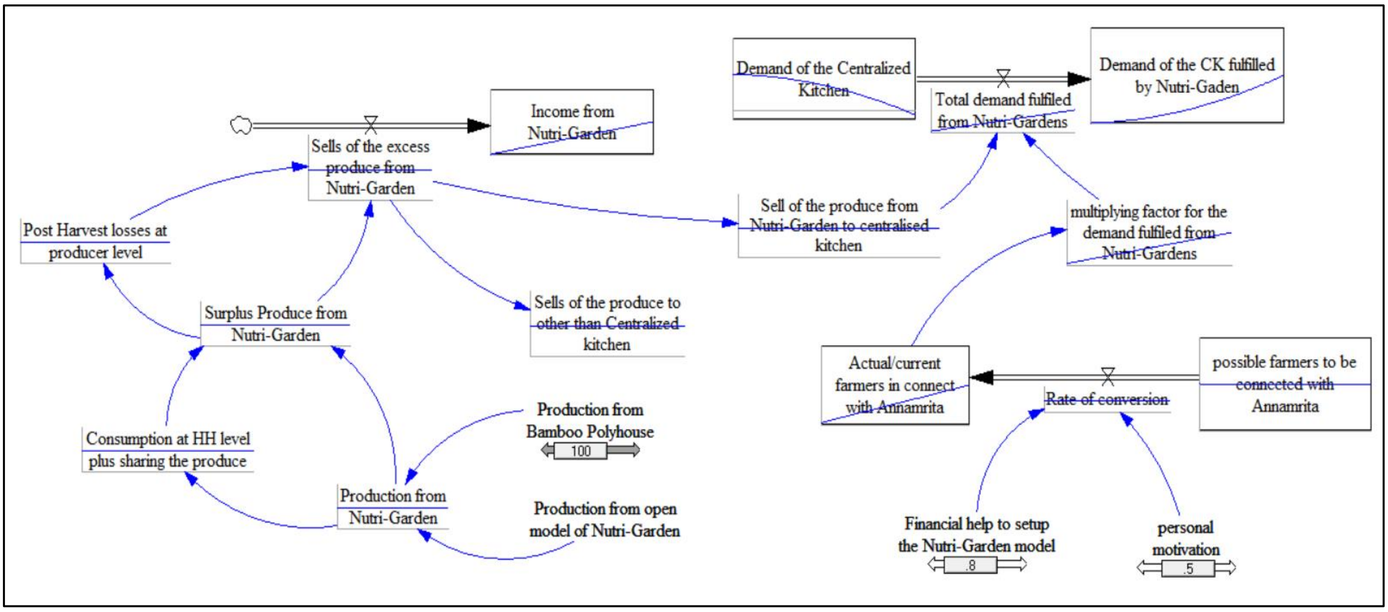
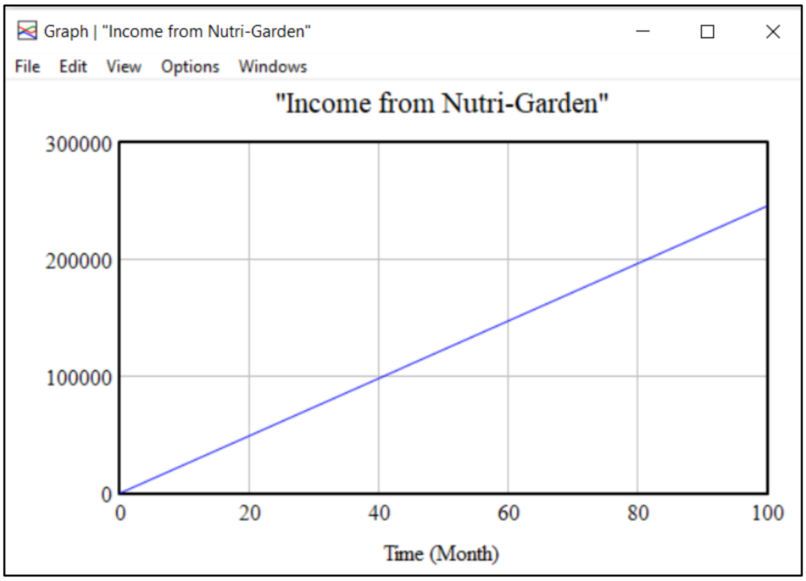


Figure 5. 5: Solution of the System dynamics model of Nutri-Garden

The results of the simulation for 100 months are as follows –

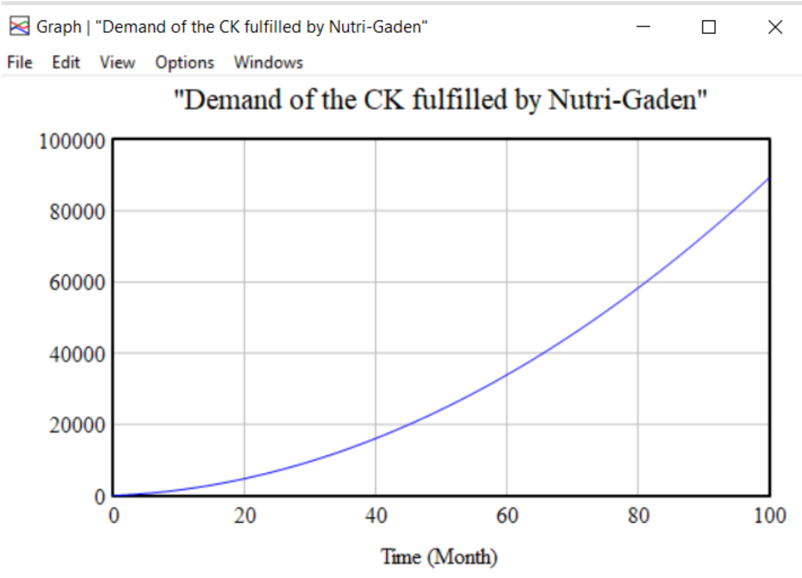
1. **Income of the farmer from the combined Nutri-Garden (Polyhouse 100 sqm + open field 100 sqm).** The linearity of the graph shown in fig 5.6 is due to no consideration of fluctuations in prices and assuming average selling price = Rs. 30/Kg



Y-axis = Income in Rs. X-axis – time in months

Figure 5. 6: Graph of the growth in income of farmer from Nutri-Garden

2. **The demand for the Centralized kitchen fulfilled through Nutri-gardens**
   During the focused group discussion at Annamrita CK, the demand of 800 quintals per day will be fulfilled after eight years as per the model results. Which tells the need of a higher conversion rate is required to dessiminate the technology.



On Y-axis = vegetable demand of CK fulfilled through Nutri-Garden output

Figure 5. 7: Per day vegetable demand of CK fulfilled by Nutri-Gardens

The above analysis has shown the possibility of engaging nearby farmers to grow nutritious vegetables through Nutri-Garden with Bamboo-Polyhouse as an add-on. This polyhouse + open cultivation Nutri-Garden model will ensure the continuous production of the vegetables. This will also help in reducing the transportation costs for Annamrita's centralized kitchen. This will add benefit to the local children, as they will be getting chemical-free vegetables through Mid-Day-Meal of Annamrita.

Chapter 6

BAMBOO STRUCTURES AND DESIGN OF BAMBOO POLYHOUSE

To achieve year-round production security from the Nutri-Garden, the protected cultivation of the horticulture crops is a good option. The conventional GI or Steel-based polyhouse was economically infeasible for a small area near 1000 sq. ft (based on quotations received from polyhouse fabricators). The literature cited below also shows the GWP of the bamboo structure is very less than that of steel or GI structure. Here comes the possibility of using bamboo instead of steel frame members in polyhouse.

6.1 Bamboo as Construction Material

Making bamboo-buildings is common in disaster-prone or earthquake-prone areas due to the resilience and lightweight of bamboo material. Many handicrafts work on bamboo material gives livelihood to some families in a rural area. Based on the variety, bamboo's compressive strength varies from 20 Mpa to 30 MPa in India (National Bamboo Code, 2005a).

Bhalla et al., (2008) developed a parabolic arch from bamboo, which can be used to develop a roof of an industrial shed or a warehouse for a farmer. This structure was designed against the wind load, dead load, live load, and their combinations. After the analysis, Bhalla et al., (2008) found that the structure is stable against the loading cases for Delhi city. Korde et al., (2014) developed a bamcrete arch by joining two bamboos with an innovative method called HIB (Haritha – IITD - bamcrete), this arch was tested under the various cyclic loading conditions. Under the increasing cycles of loading, this arch showed linear structural behavior up to 15 MPa of compressive stress.

Yadav et al., (2014) did an experimental study to check the feasibility of a low-cost bamboo polyhouse for the nursery and vegetables for India's north cold climatic region. The report did not explain much about the structure; still, the component details of the polyhouse explained the local joinery methods used for 50 sqm polyhouse. Jadhav and Rosentrater (2017) developed a Bamboo-Polyhouse of 192 sqm (8m*24m) for vegetable (tomato) cultivation. The polyhouse was constructed for the Konkan region of Maharashtra (hot and humid climate). The foundation was made with concrete + PVC pipes, and the gap between the bamboo column and PVC pipe was filled with cement mortar. The connections and joinery is made with the help of metal clamps, strips and Nut-Bolts. This study did not explain the structural stability details, but it concluded by financial analysis, which showed 28% cost savings than steel/GI polyhouse. Global Warming Potential (GWP) of the Bamboo-Polyhouse was found to be 5 Kg of CO_2/sqm of polyhouse, which is nearly one-fifth of the GWP of GI polyhouse (26.9Kg of CO_2/ sqm).

*Figure 6. 1: Bamboo Polyhouse of 8m*24m (Yadav et al., (2017))*

6.2 Understanding the Bamboo Structures through field Visit

To understand the details about the structures developed from the bamboo, we did a field visit to the Nashik District of Maharashtra. The visited sites were constructed by Eastern Star Company. This company provides the consultancy, service, and construction of the protected cultivation units. One of the structures is developed for protected cultivation experimentation, and another is used as an industrial shed. Following are the findings from the field visit:

- The bamboos used in the structure are of around 2.5-inch diameter
- Both the structures have survived for more than a year and still functioning properly
- For the foundation, proper concreting was done
- Bamboos were joined using a fabricated clamp of Mild Steel
- The slots at the end of bamboos were made to make the joinery, as shown in figure 6.2
- It observed that using green bamboo used in structure shows more tendency towards crack propagation
- The operations which require holes were performed by drill only

- Based on the life of the structure and quality of performance observed through field visit, we decided to get help from this company for erecting the bamboo polyhouse

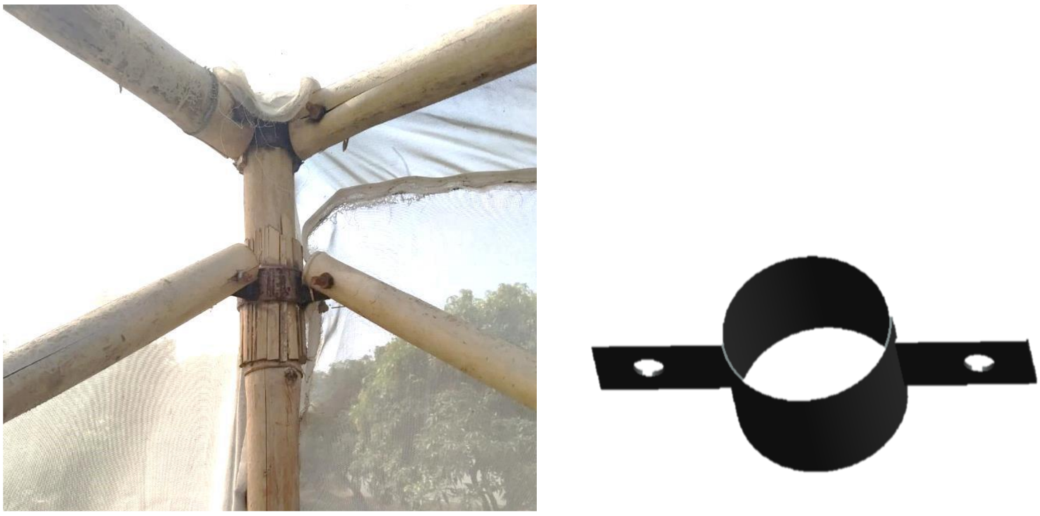


Figure 6. 2: Joinery method observed during Bamboo Structure visit

- Following are the full sized views of the bamboo structures from Nashik district

Figure 6. 3: Bamboo structures visited during the field visit a. Structure used for protected cultivation experiments, b. a structure used as an industrial shed

From the literature survey and field visits, we understood that bamboo could be used as a construction material for a polyhouse. One should select treated bamboos for construction, which will take care of the termite and borer attack. Joinery is another challenging procedure in making bamboo structures.

6.3 Guidelines followed to design the Bamboo Polyhouse for Jawhar and Vikramgad Blocks of Palghar district

As the study areas have geographic variation (Jawhar is at around 300m above sea level, and Vikramgad is 60m above sea level), we need to follow specific guidelines for defining the height, orientation, and equipments required for polyhouse. Following are the technical specifications given by National Horticulture Board (NHB, 2011) considered before designing the Bamboo-Polyhouse:

- Site selection –
    - The site should be free from the shadows
    - The site should be at a higher elevation than the surrounding, for the drainage facility
    - There should be irrigation water availability
    - pH of the water should be in the range of 5.5 to 7 and EC between 0.1 to 0.3mS/cm
    - pH of the soil should be in the range of 5.5 to 6.5
- Height of the polyhouse
    - For naturally ventilated polyhouse of size less than 250sqm, the height should be in the range of 3.5 to 4.5m
- The orientation of the polyhouse
    - According to IS 14462: 1997, section 5.3, the greenhouse orientation should be such that the gutter or ridge should orient the East-West direction. It means that the length of the polyhouse should be oriented along North-South Direction
- Natural Ventilation of the greenhouse
    - According to IS 14485: 1998, Section: 8, natural ventilation in the polyhouse occurs due to the pressure difference. A wind or temperature gradient can obtain this pressure difference. This IS code tells the suitability of natural ventilation in warm or hot arid climates.
    - The combined side vent area should be equal to the combined ridge vent area
    - The vent area should be 15 to 20% of the wall or surface area
    - The vent area should make a 60-degree angle with a roof area
    - Evapotranspiration cooling – to get an advantage in natural ventilation plants with a higher evapotranspiration rate will help in creating a cooling effect (IS 14485, section 8)

- Stability of the structure – structure should remain stable against wind speed of 36m/s or 42m/s for the high wind speed regions (NHB, 2011)
- Foundation for the polyhouse – as per IS 14462, section 6, foundation footing should be made with a minimum depth of 600mm below ground surface.
- The span of the polyhouse – if the area of the polyhouse is less than 250 sqm, then we can design it with a single span area (NHB, 2011)
- Bottom apron – to trap the CO2 inside the polyhouse bottom apron should be taken up to 0.6m to 1.5m in height (NHB, 2011)
- Top and side shading materials (Polyfilm and shed-net) –
    - Top shading (Polyfilm) specifications – 200 microns (0.2mm) thickness, density should be around 900 to 1000 Kg/m^3 (5.4 sqm polyfilm can weigh 1kg). This polyfilm should be UV stabilized
    - Side shading material – for side shading, two materials are preferred with following specifications (NHB, 2011):
        - Shed net with 35% (can block 35% of sunlight) rating should be used for side walls. It should have minimum 75 GSM
        - Insect proof net with 40% mesh (40 holes per inch) and must have at least 100 GSM (100 gram per sqm) weight
- Other fixtures – to fix the polyfilm, shade net, or bottom apron, one should not fix it by a nail; it should be fixed using aluminum profiles and zig-zag springs.
- NHB, (2011) guidelines suggest using an exhaust fan along with natural ventilation in both hot and cold regions

The above guidelines are considered before selecting the materials and designing a polyhouse for the Jawhar and Vikramgad regions.

6.4 Design of the Bamboo Polyhouse

After going through the basic polyhouse structures for a small area of around 100 sqm, we decided to go with natural ventilation. The structural details of the polyhouse were designed with the help of the Eastern star company. The sectional views of the designed polyhouse are shown in figure 6.4. The structural analysis of this polyhouse is done in the next chapter.

Based on the available polyfilm width in the market, we have optimized the area (span) of the polyhouse to 128 sqm—this saved material wastage. The height (4.5m) of the polyhouse orientation (North-South) and location of the site was selected based on the guidelines given by NHB and IS codes.

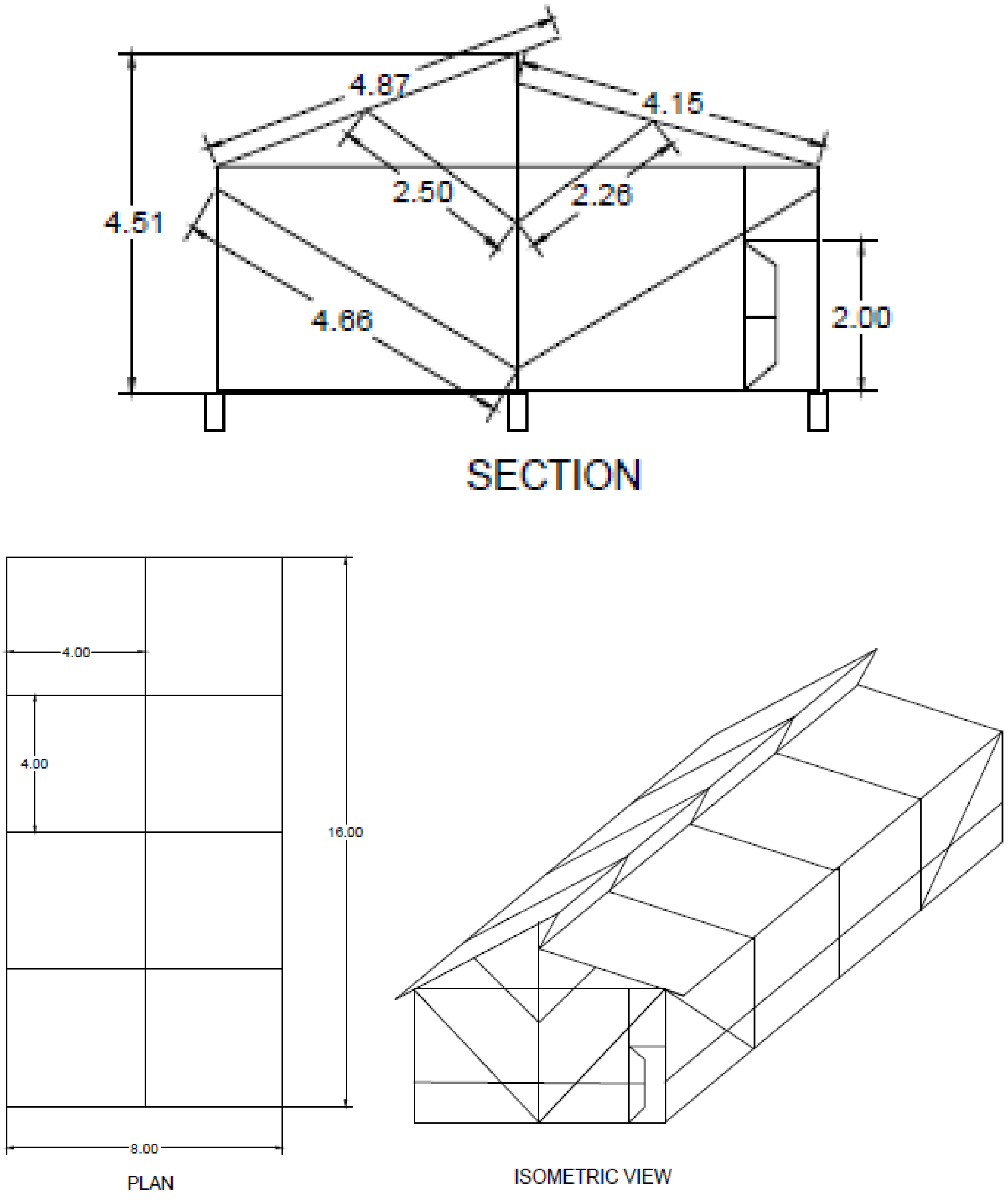


Figure 6. 4: Sectional Plan and Isometric view of the designed Bamboo Polyhouse

6.5 Materials and their specifications

The materials for the polyhouse were selected as per the guidelines mentioned in section 6.3 of this chapter. Bamboo specifications for polyhouse are not mentioned in the guidelines of

NHB or IS codes. Therefore bamboo selection was made based on the treatment method, its proposed life, and cost.

6.5.1 Bamboo selection and procurement

The local bamboo available in the market (in Bamboo Vakhar) is not the treated one. After contacting several vendors in the region of Nashik, Pune, Thane, Gujrat, and Mumbai, which were available on indiamart.com, none of them were aware of the treated bamboos. After getting the reference of treated bamboo providers from the Pune, Nagpur, and Konkan regions of Maharashtra, we selected the economical vendor who sells the bamboo with a certified treatment method. The available treated bamboo was of *Dendrocalamus Stocksii* variety and locally known as *Mes Bamboo.* The bamboo provider claims that this bamboo is not exactly of the *Dendrocalamus Stocksii* species and can get a different name from the existing species when scientifically studied.

The treatment method used was of CCB type. CCB is a chemical treatment method used when bamboo needs to be stored for a long period. CCB consists of boric acid, copper sulfate, and sodium dichromate in the ratio of 1.5:3:4.

Figure 6. 5: Observable difference between 1) non-treated bamboo, 2) treated bamboo, and 3) treated bamboo with polish (Pic credit – Mr. Vinay Kolte)

Mechanical properties of *Dendrocalamus Stocksii* –

IS 15912: 2018 does not have the properties for the *Dendrocalamus Stocksii;* hence we have used the properties corresponding to *Dendrocalamus Strictus.* The compressive and crushing strength of the *Dendrocalamus Stocksii* is found greater than the *Dendrocalamus Strictus.*

Table 6. 1: Mechanical Properties of Dendrocalamus Stocksii

Property Name	**Value For D. Stocksii**
Density (in green condition)	691 (Vishwanath et al., 2013)
Density (in dry condition)	728*
Maximum Crushing stress	38.6 MPa (Vishwanath et al., 2013)
Modulus of Elasticity	15GPa*
Max Compressive strength	69.1 MPa*
Mod. Of Rupture	119.1 Mpa*

**indicates the values assumed for D. Stocksii based on D.strictus*

The above properties in dried conditions were used for the analysis of the structure in ETAB Software.

6.5.2 Other than Bamboo material selection and properties

By following the guidelines for a polyhouse, the material was selected and purchased from the Nashik. The following table shows the bill of material for polyhouse –

Table 6. 2: Materials used and their specifications

Sr. No	**Material Name**	**Specification**
1	Polyfilm	200 micron, UV stabilized, used for top shade
2	Insect Proof Net	40 Mesh size, 200 GSM, Used for sidewalls
3	Half clamps and full clamps	Metal (GI) clamps, Used for joinery at specific locations
4	Metal strips	Fabricated from GI sheet with specific dimensions for the joinery
6	Nut Bolts and self-driven screws	Made up of MS material and galvanized for rust resistance
7	Pre-cast foundations	The foundations were pre-casted in the workshop, using cement mortar, steel rods for reinforcement, and GI pipe to support the bamboo column
8	G-Fab sheet (Geomembrane Fabric sheet)	This sheet is similar to the polyfilm and uses as a bottom apron to trap the CO2 inside the polyhouse
8	GI wire	Geomembrane Fabric sheet is fixed along the walls of polyhouse using this wire

Chapter 7

STRUCTURAL ANALYSIS OF BAMBOO POLYHOUSE

It is essential to understand a structure's performance under dead load, live load, and wind loads. This chapter will be looking into the results and conclusions based on analysis of the Bamboo-Polyhouse in "ETAB 17" software.

7.1 General structural details

The 3D geometry of a single-span bamboo polyhouse structure is shown in the following Figure 7.1.

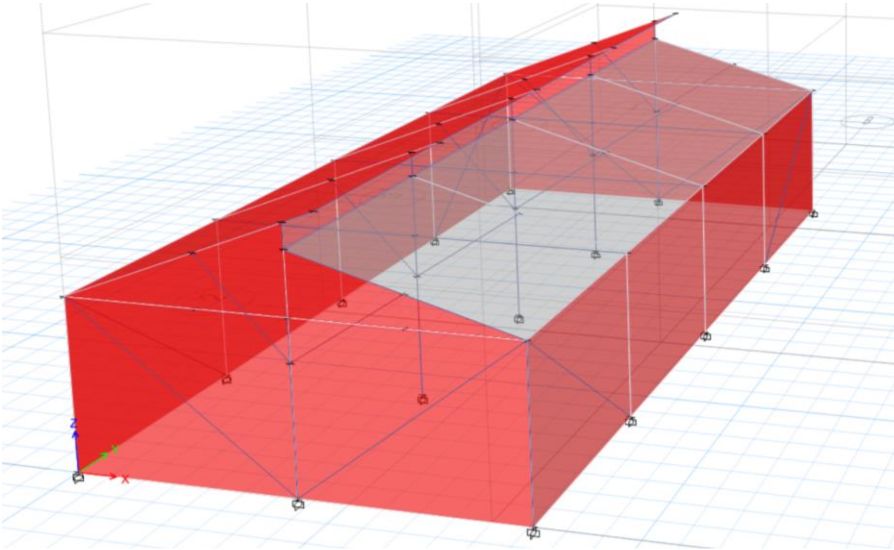


Figure 7. 1: 3D model of Bamboo-Polyhouse from ETAB 17

Based on the above diagram, details of every structural member are mentioned in Table 7.1.

Table 7. 1: Specifications of the structural members

Sr. No.	Member Name	Dimensions	Quantity (Number of Bamboo Poles)
1	Central Columns	4.5m	5
2	Side Columns	3m	10
3	Long Rafters	4.87m	5
4	Short Rafters	4.14m	5
5	Top Purlins (beams along length)	4m	4*2 = 8
6	Side Purlins (beams along length)	4m	4*2 = 8
7	A brace from the central column to the longer rafter	2.7m	5

8	A brace from the central column to the shorter rafter	2.5m	5
9	Braces Joining Corner Column and their adjacent columns	4.67m	8
10	Bottom tie (Beams along the width)	4m	10
Total Members			69

7.2 Defining the properties in the ETAB software

To make a 3D model of polyhouse in ETAB different assignments related to member size, material properties, surface properties, load assignments, joint restrictions, etc., were provided. As bamboo is not available for numerical analysis in ETAB, we have created a new material and assigned the following properties to the structural member elements.

Table 7. 2: Properties assigned in ETAB

Sr. No.	Property Name	Assigned value with units
1	The density of a Bamboo	728 Kg/m^3
2	Modulus of Elasticity	15 GPa
3	Minimum Yield stress	60 MPa
4	Minimum Tensile strength	48.5 MPa (Kurhekar et al., (2015))
5	Maximum Compressive strength	69.1 MPa (IS 15912)
Sectional Properties of bamboo members		
1	Cross-sectional details	Outer Dia – 65 mm Inner Dia – 35 mm

All the base joints are assigned fixed constraints, and all other joints are assigned pinned connections. After the joints and member properties, the properties for polyfilm material and wall / slab section were assigned.

Table 7. 3: Properties assigned to shell section in ETAB

Sr. No	Property Name	Value assigned
1	Density of a polyfilm	1000 Kg/m^3
2	Thickness of the wall/slab	0.2mm
3	Modulus of Elasticity for HDPE polyfilm	1000 MPa

7.3 Assignment of the loads in ETAB

To analyze the bamboo-polyhouse model in ETAB, we have to define the load patterns. As there will not be any live load on the structure, we will be considering the dead loads and wind loads.

7.3.1 Calculations for dead load

The dead load for the structure will be of its self-weight only. Based on the density and volume of the bamboos and polyfilm, we have calculated the dead loads as follows –

$Self\ weight\ of\ the\ Bamboo = mass \times g = density \times volume\ \times 9.81$..............(1)

$$mass = 728 \times \frac{\pi}{4} \times (65^2 - 35^2) \times effectivelength\ of\ bamboo\ members\ \times 9.81$$

$$total\ mass = 356.8\ Kg$$

$$Total\ dead\ load\ by\ Bamboos\ in\ KN =\ 0.024 \frac{KN}{m^2}$$

Similarly, the dead load of the polyfilm contributed $0.002\ \frac{KN}{m^2}$ of dead load

$$\boldsymbol{Total\ dead\ load =\ 0.026\ \frac{KN}{m^2}}$$

7.3.2 Calculations for wind load

To calculate the wind loads applied to a structure, we have used IS 875 Part 3: 2015.

Wind load Calculations – using IS 875 Part 3, 2015.

- Assumptions –
  - $maximum\ wind\ speed\ (\ V =\ 44\ m/s)\ (Figure\ 1, IS\ 875, Part\ 3{:}\ 2015)$
  - $Risk\ Coefficient\ =\ K1\ =\ 0.91\ (Table\ 1, clause\ 6.3.1, IS\ 875)$
  - $K2\ =\ 1\ (Table\ 2, Clause\ 6.3.2.1\ b\ )$
  - $K3 = 1$

    $(as\ the\ topography\ factor\ is\ one\ due\ to\ less\ than\ 3\ degree\ slope)$
  - $K4\ =\ 1\ (As\ both\ the\ sites\ are\ more\ than\ 60Km\ from\ coastal\ area$

    $importance\ factor\ is\ 1)$

- $Vz = k1 * k2 * k3 * k4 * V$ … … … … … … … … … … … … … … … … … … … . . … … … (2)
- $Vz = 44 * 0.91 = 40.04\, m/s$
- $Pz = 0.6 * Vz\,\hat{}2 = 961.92$
- $Pd\ (Design\ Wind\ pressure) = Kd\ (directionality\ factor) * Ka (area\ avg\ factor) * Kc\ (pressure\ combination\ factor) * Pz$

$$\boldsymbol{Pd = 701.24\ N/sqm} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(\mathbf{3})$$

Finding external and internal pressure coefficients –

Based on the height to width ratio, external pressure coefficients are given in the IS 875, Part 3, Table 5. For our structure, height – 4.5m and width is 8m. Figure 7.2 will help in identifying the surfaces in the table 5 of IS 875.

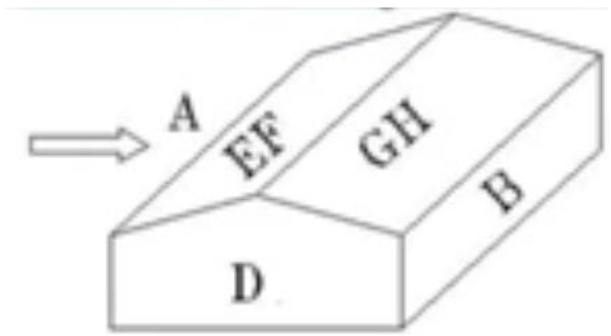


Figure 7. 2: Orientation and names assigned to the polyhouse surfaces

According to section 7.3.1 of IS 875, Part 3, total Cp (pressure coefficient) = (Cpe-Cpi)

Where Cpi is the internal pressure coefficient and depends on the percentage air resistance offered by the walls.

Table 7. 4: Internal pressure coefficients for different opening percentage on walls

Sr. No	Percentage opening	Cpi (Internal Pressure Coefficient)
1	0 to 5 % opening	0.2
2	5 to 20% opening	0.5
3	More than 20% opening	0.7

In our design, walls are made up of a 40% mesh insect-proof net. 40% mesh means 40 holes per inch, and the diameter of the holes in insect-proof net is 0.26mm.

$$\therefore percentage\ opening = \frac{area\ of\ the\ holes}{total\ wall\ area} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Consider for one square inch insect-proof net; there will be $40 \times 40 = 1600\ holes$

$$each\ hole\ area = \frac{\pi}{4} \times 0.26^2 = 0.0531\ mm^2$$

$$Total\ Hole\ area = 1600 * 0.0531 = 84.96\ mm^2$$

$$one\ inch = 25.4\ mm$$

$$\therefore One\ inch\ square = 25.4 \times 25.4 = 645.16\ mm^2$$

Therefore,

$$Percentage\ opening\ for\ the\ net\ material\ is = \frac{84.96}{645.16} = 13.17\%$$

Therefore we will be having the side walls with opening less than 13.17%.

$$Therefore\ from\ Table\ 7.4$$

$$\boldsymbol{Cpi\ =\ +/-\ 0.5}$$

The following table shows the wind load calculations for different cases and different surfaces.

Wind Load = F = Cp*Pd* Area……………………………………………(5)

Table 7. 5: Wind Pressure Calculation with wall pressure coefficients

Case 1: Wind across the Ridge Zero degree +ve Cpi				
Surface	**Cpe**	**Cpi**	**Cp=Cpe-Cpi**	**Wind Pressure N/sqm**
A	0.7	0.5	0.2	140.2481
B	-0.3	0.5	-0.8	-560.992
C	-0.7	0.5	-1.2	-841.488
D	-0.7	0.5	-1.2	-841.488
EF	-0.7	0.2	-0.9	-631.116
GH	-0.5	0.2	-0.7	-490.868
Case 2: Wind across the Ridge Zero degree -ve Cpi				
Surface	**Cpe**	**Cpi**	**Cp=Cpe-Cpi**	**Wind Pressure N/sqm**
A	0.7	-0.5	1.2	841.4885
B	-0.3	-0.5	0.2	140.2481
C	-0.7	-0.5	-0.2	-140.248
D	-0.7	-0.5	-0.2	-140.248
EF	-0.7	-0.2	-0.5	-350.62

GH	-0.5	-0.2	-0.3	-210.372
Case 3: Wind parallel to the Ridge 90 degree +ve Cpi				
Surface	**Cpe**	**Cpi**	**Cp=Cpe-Cpi**	**Wind Pressure N/sqm**
A	-0.5	0.5	-1	-701.24
B	-0.5	0.5	-1	-701.24
C	0.7	0.5	0.2	140.2481
D	-0.1	0.5	-0.6	-420.744
EF	-0.8	0.2	-1	-701.24
GH	-0.8	0.2	-1	-701.24
Case 4: Wind parallel to the Ridge 90 degree -ve Cpi				
Surface	**Cpe**	**Cpi**	**Cp=Cpe-Cpi**	**Wind Pressure N/sqm**
A	-0.5	-0.5	0	0
B	-0.5	-0.5	0	0
C	0.7	-0.5	1.2	841.4885
D	-0.1	-0.5	0.4	280.4962
EF	-0.8	-0.2	-0.6	-420.744
GH	-0.8	-0.2	-0.6	-420.744

After calculating the wind coefficients, the shell-wise loading was done in ETAB software. ETAB asks for the wind velocity, different factors as discussed above (K1, K2, K3), the pressure coefficient for the surfaces, and the software automatically computes the loads. After defining the load cases for wind along and across the ridge, wind pressure coefficients and dead loads were applied on shells.

In ETAB 2, load combinations were defined –

1) Dead Load + Load due to Wind along X – direction

2) Dead Load + Load due to Wind along Y – direction

7.4 Simulation of the Bamboo-Polyhouse model and results

After simulating the model in ETAB, it generates the results for deflections, axial forces in members, shear forces, and bending moments. Instead of performing analysis by hand "Design" tab in ETAB software helps in directly knowing the failure of the members. Following options were selected in the ETAB design before the simulation

1. Selected the IS 800:2007 code for design analysis
2. The factor of safety was considered as 2
3. The seismic zone was ignored for the analysis

All the members were safe after simulating the model against 44m/s wind speed.

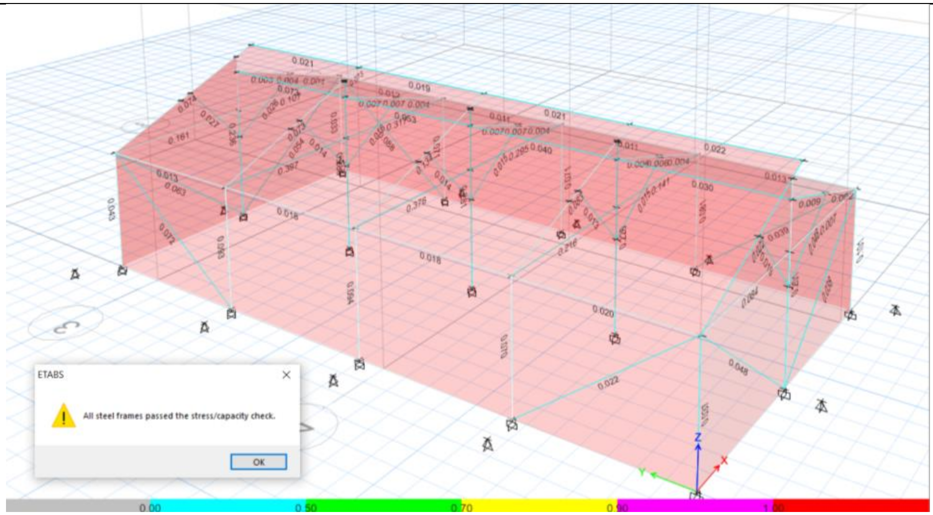


Figure 7. 3: ETAB simulation results for the wind speed of 30 m/s

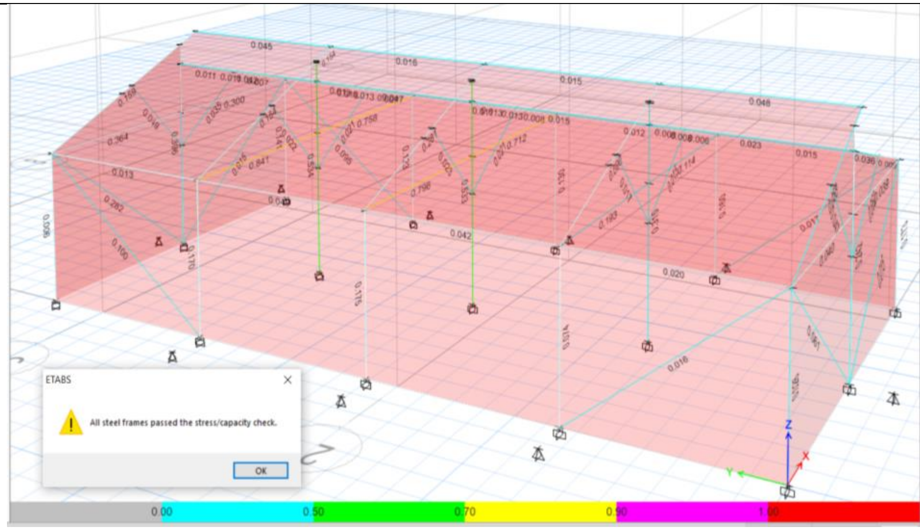


Figure 7. 4 ETAB simulation results for the wind speed of 40 m/s

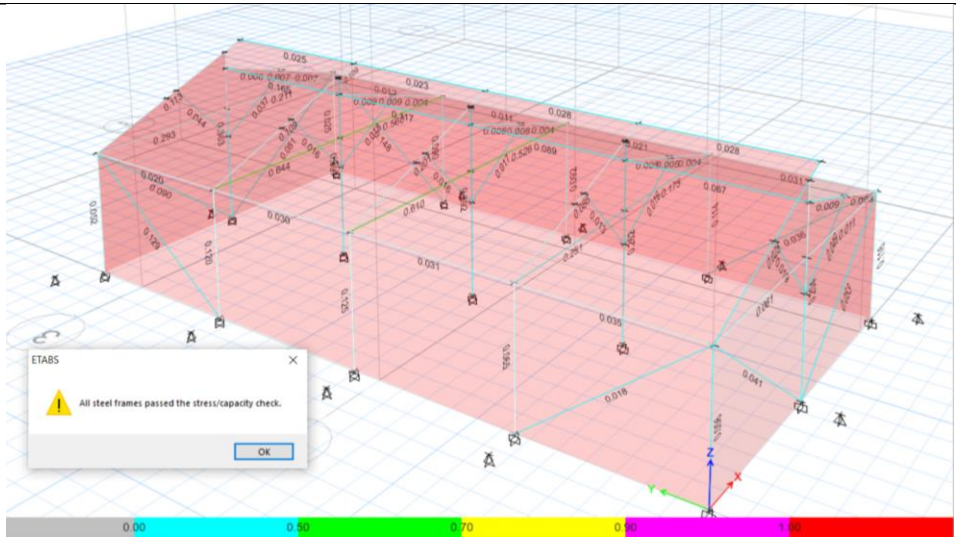


Figure 7. 5 ETAB simulation results for the wind speed of 36 m/s

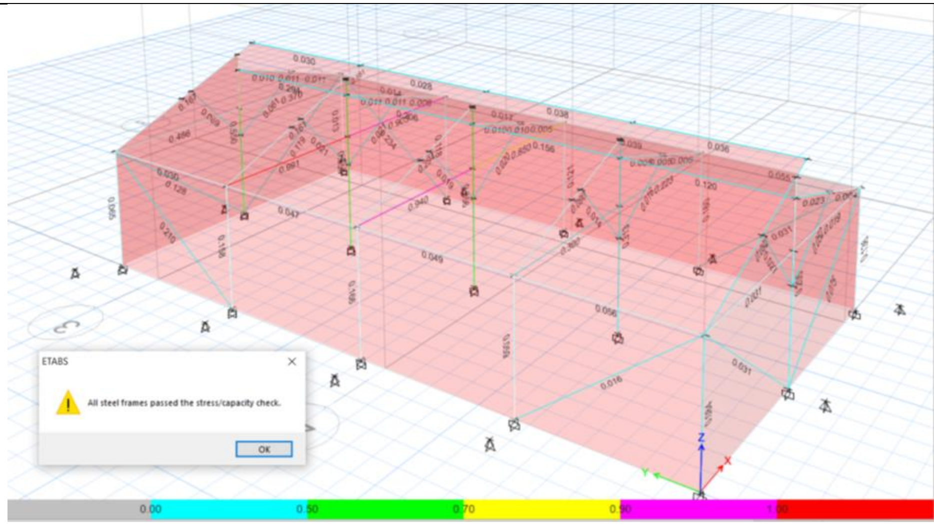


Figure 7. 6 ETAB simulation results for the wind speed of 44 m/s

Figures 7.3 to 7.6 show the structural members' overall view in a color-coded format, where near to red color structure is critically loaded. These figures show the behavior of the members against different load combinations for different assigned wind speeds.

All the members are below 50% of the maximum allowable stresses for 30 m/s of wind speed. For 44 m/s of wind speed, stresses in 3 members reached above 90% of the permissible stress value with a factor of safety = 2.

This simulation also generated the deflection values for different load combinations at different joints

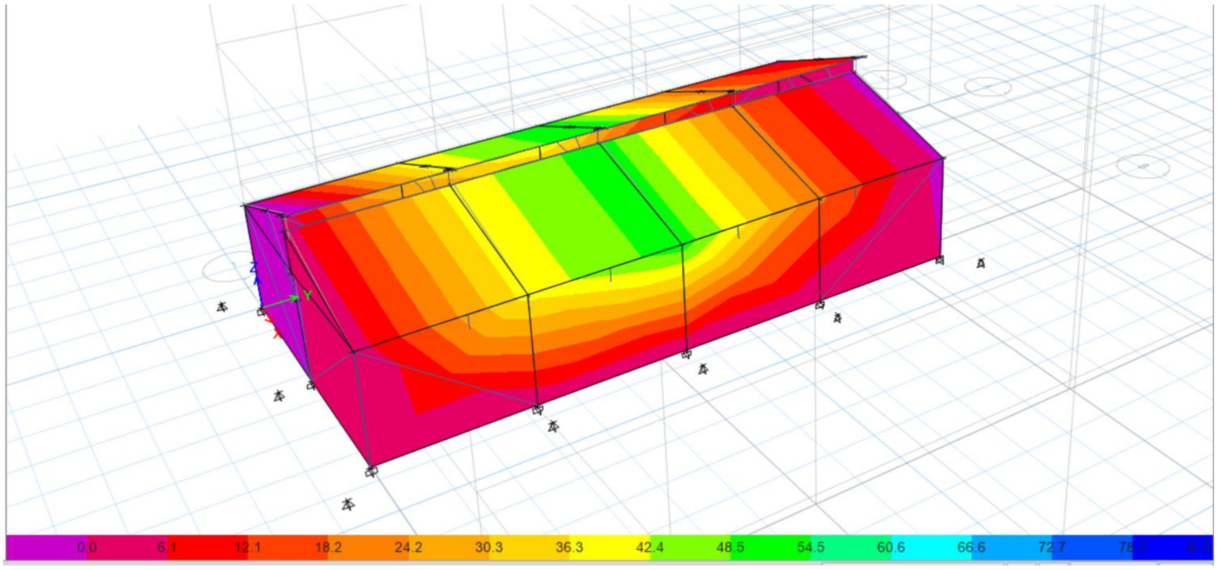


Figure 7. 7: Deflection of the points due to the wind load of 44 m/s and scale factor of 50

Maximum deflection observed for the dead load + wind along the X loading case is 3.57 mm. Similarly, axial forces, bending moments, and base reactions are obtained through the ETAB software report. After knowing the safety of the members for the corresponding loading pattern, the detailed theoretical analysis is not performed for different frames. Frame number 4 in +ve y-direction of figure 7.6, found to be critically loaded. This is because maximum Cp = 1.2 was observed on wall ‘C.’

The following figure 7.8 is representing the axial forces in the structural members. The red color represents the members under compression, and yellow represents the members under tension. The 5th central column experiences the highest compressive axial force = 5.3 KN.

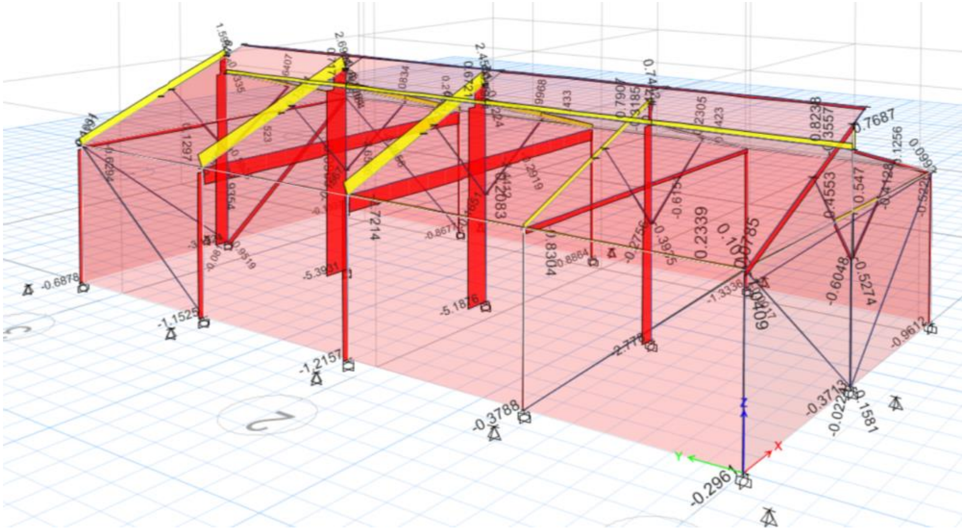


Figure 7. 8: Diagram representing the Axial forces in the Beams and columns

Further analysis for this bamboo structure can be done using a limit state of strength and limit state of serviceability for bamboo material.

In this way, we have performed an analysis of the structure using software simulation and found that structure is safe under different loading combinations.

Chapter 8

CONSTRUCTION OF THE BAMBOO POLYHOUSE

After designing and software-based simulation, the model was found to be safe. In this chapter, we will be covering the construction details of the bamboo polyhouse. Two bamboo-polyhouses of 128 sqm span are erected at Balapur village of Vikramgad block and Ramkhind village of Jawhar block. Both the blocks are in the Palghar district. The major objective of erecting these polyhouses was to provide the protected cultivation for the rural household. This polyhouse will ensure year-round nutritional security and help farmers to sell the surplus to improve their wealth index. The minute details related to operations, techniques, and equipment used in building the bamboo polyhouse are covered in this chapter.

8.1 Site selection, measurements, and Foundation preparation

Based on the guidelines described in chapter 6, sites were selected in the Balapur and Ramkhind villages of the Palghar district. Both the sites were at an elevated location, which will ensure water drainage.

Figure 8. 1: Site selection and measurements made for the foundation for 1) on the left side- Balapur site 2) on the right side- Ramkhind site

After selecting the site, the measurements were done using 100m measuring tape, and markings for foundation pits were done. The farmer did digging of the pits for the foundation of 2ft deep and 1.5 ft * 1.5 ft area. The north-south orientation was selected along the length of the polyhouse.

After this, the pre-cast foundations were made in the workshop in Nashik. The dimensional details of this foundation are mentioned in figure 8.2. The foundation consists of

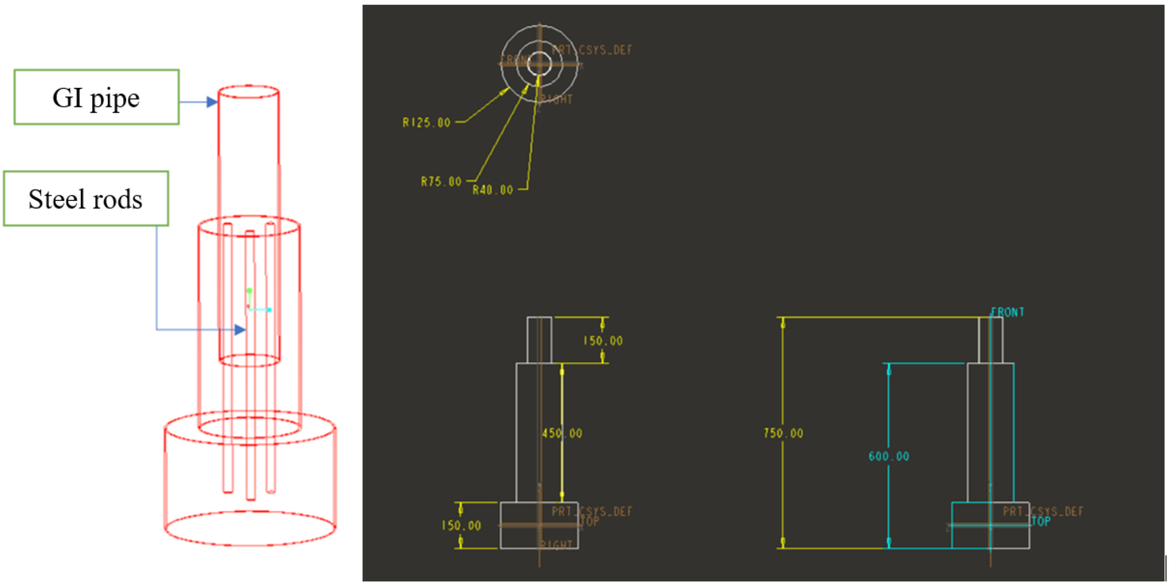


Figure 8. 2: CAD drawing of the pre-casted foundation

These precast foundations were put in the pits of the foundation. While working on the frame, foundations were cracked due to the moment generated from a worker's live load. The whole set of foundations was again made with the in-situ foundations using sand and cement mortar. Following figure 8.2 shows the crack in the pre-cast foundation and coping strategy of the in-situ foundation

Figure 8. 3: On left – crack in Pre-Cast Foundation, On the right – in-situ foundation using cement mortar+sand+stones (Pictures captured at Balapur site)

After the Foundations Frames of the polyhouse were prepared

8.2 Frame preparation and fixing of the purlins

The span of polyhouse is 16m * 8m, along the length of 16m – 5 frames 1 at each 4m distance was erected. One frame consists of – one central column of 4.5m, two side columns of 3m each, a long rafter of 4.87m, a short rafter of 4.15m, a long brace of 2.7m, a short brace of 2.5m, and two bottom ties of 4m.

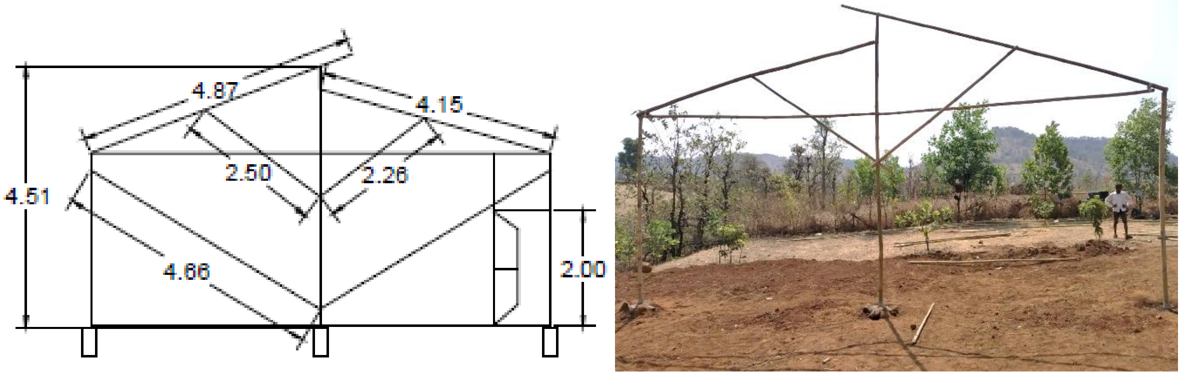


Figure 8. 4: On left – designed frame of polyhouse and on the right – fabricated frame of polyhouse

The joinery details for the frame are as follows –

- The central column and the bottom ties (4m beams) were joined using metal strips, nut-bolts, and self-driven screws. The joinery of the central column and bottom ties is shown in figure 8.5 –

Figure 8. 5: joinery of bottom ties and central column

- The central column and short rafter were joined using the metal clamp, as shown in the following figure 8.6 –

Figure 8. 6: Joinery for the central column and short rafter

- Joints between braces and central columns were made by lap joint (as specified in IS 15912: 2018). Here the J-type bolt was used instead of normal nut and bolts.

Figure 8. 7: Lap joint for joining two braces with central column

- The joint between the central column and long rafter is made by inserting a fabricated metal strip in the central column's top end and then fixing it with the metal clamp. At the second polyhouse site, the connection was made directly by metal clamp without inserting the metal strip.
- Top-end of the side column and rafter were joined using the same joinery method used for joining central columns and long rafter
- The bottom ties were fixed with short and long rafters near the side column end using two metal clamps.

- As per the specifications given in the IS 15912: 2018, bamboos were filled with the inserts at the ends before joining. This is shown in the following figure 8.8 –

Figure 8. 8: Bamboo inserts for strengthening the joint

These small bamboo inserts will help in increasing the shear area for the joint, and it will restrict the movements of fasteners over time.

- The columns' bottom ends were inserted in the foundation's GI pipe and then fixed with long nut-bolts.

Figure 8. 9: Erected frames of the polyhouse (Image from Ramkhind site)

Profile strips of aluminum were fixed at the required locations before raising the structure. Figure 8.9 shows the erected structure of the bamboo polyhouse.

- After erecting the five frames, the side and top purlines were joined.
    - The purlins of 4m each were joined on the ground to form a 16m long purlin. Then this long purlin was raised over the frames using wire ropes.
    - The purlins were joined using insert, side plates, and sleeve type of joint as mentioned in IS 15912:2018. They are shown in the following figure 8.10 -

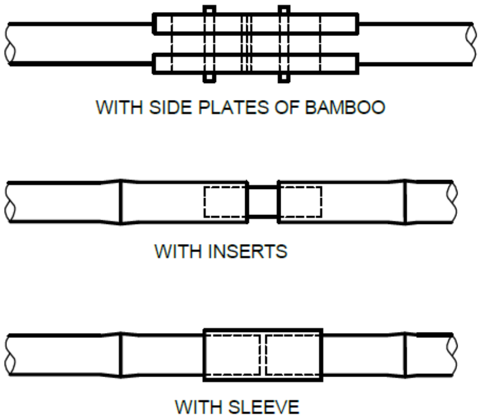


Figure 8. 10: Butt Joint used for connecting the purlins along the length of polyhouse (IS 15912: 2018)

8.3 Fixing the polyfilm, side net, and door

After finishing the joinery and all structural work, the polyfilm was fixed over the top floors. The Insect-proof net was fixed before fixing the polyfilm at the end of smaller side columns. Aluminum profile strips along with zig-zag springs were used to fix the shading material. The polyfilm was raised over a structure using wire rope.

The location of the door was selected based on the convenience of the farmer, and it is avoided to keep it on the west side for the second polyhouse. The G-Fab sheet was used to cover the door openings. As the structure is small headhouse is not constructed. The locking of the door is made from metal strips.

After finishing all construction activities, the structure of the polyhouse is shown in the following figure 8.11 –

Figure 8. 11: Completed Bamboo Polyhouse structure from Ramkhind Village

Figure 8. 12: Completed Bamboo polyhouse structure from Balapur village

After finishing all construction works, drip fitting, soil preparation, bed preparation, sapling transplanting, and sowing activities were done.

8.4 Drip System design and installation

To irrigate the vegetables inside the polyhouse, drip irrigation is the best way. For these polyhouses we have designed a gravity-based drip irrigation system. One of the farmers is having a 0.5HP electric motor, and one is having a 0.5 HP solar pump; based on that, we have also provided them a micro-sprinkler set.

Firake et al., (2016) did an experimental analysis to find the effect of irrigation water supply on the yield of the tomatoes under a polyhouse located near Ahmednagar, Maharashtra. The author found the best yield for the irrigation level = 95% of the ETc. They found a maximum of 3.15L/sqm/day of the irrigation level is required. Therefore for 128 sqm area, we will need

$$= 128 * 3.15 = 403.2\ L/128sqm/day$$

When directly calculated based on 5cm irrigation water requirement, the daily water requirement is -

$$= 640\ L/128sqm/day$$

As per IS 14462: 1997, irrigation water requirement for raised bed cultivation in polyhouse = 20 $L/\ sqm/day$. This value is for flood irrigation; by assuming 50% water saving due to drip, we will need $10L/sqm/day$. For 128 sqm, the water requirement will be 1280 L/day.

Therefore by considering all 3 cases, we have selected a tank size of 1000 Litres.

Out of drip inlines and drippers, we have selected the drip inlines. The discharge rate from the drip inline is 4 L/hr, which is assumed to give 2 L/hr when water supplied is from a 1m elevated gravity-based head.

Figure 8. 13: Elevated Tank for drip

Figure 8. 14: Drip inlines place over the raised beds

Figure 8.13 shows the elevated foundation for the drip water supply tank. Figure 8.14 shows the drip inlines placed over the raised beds. The inlines are having the outlets at every 1.5 Ft. This will be considered while transplanting the saplings and sowing the new seeds.

Chapter 9

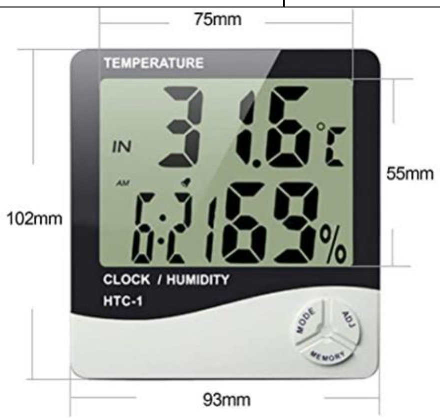
SPATIAL AND TEMPORAL ANALYSIS OF NATURALLY VENTILATED POLYHOUSE MICROCLIMATE

It is essential to know the temperature variation and ventilation for the polyhouse with natural ventilation and installed in hot regions—both the regions where sites are located come in hot areas. In the Jawhar block, the temperature remains 1 to 2 ^{0}C above the temperature of Vikramgad. In this chapter, we are going to see the variation in temperature w.r.t. time and location inside the polyhouse.

9.1 Tools used for data collection and objectives of the analysis

To get the data for temperature, humidity, and wind speed, we used HTC – 1 Hygrometer and vane type digital anemometer as shown in the following table

Table 9. 1: Specification details of the measurement sensors

Parameter	**HTC 1 thermometer**	**HTC-1 hygrometer**	**Vane type Digital-Anemometer**	**Inbuilt temperature sensor in Digital Anemometer**
Range of measurement	-50 to +70 degree celcius	10% RH to 99% RH	0.4 m/s to 30m/s	0 to 60 ^{0}C
Resolution	0.1^{0}C	1%	0.1	0.1^{0}C
Accuracy	+/- 1 ^{0}C	+/- 5%	+/- (2%+1d)	0.5^{0}C
Image of the Instrument	 *Figure 9. 1: HTC thermometer+hygrometer*		 *Figure 9. 2 Digital Anemometer*	

The objectives of this analysis were –

- To know the difference in temperature inside polyhouse and outside the polyhouse
- To understand the variation in the temperature within the polyhouse along the area (span) and along the elevation
- To understand the wind flow and ventilation in the polyhouse
- To understand the ventilation effect in polyhouse for different wind speeds using Computational Fluid Dynamics.

9.2 Methodology for data collection

To get the spatial and temporal data of temperature, humidity, and wind speed, we have used the following methodology

- Data were collected for two days. On 10th March 2021 at Ramkhind (Jawhar) site and on 11th March 2021 at Balapur (Vikramgad) site
- 2 HTC thermo-hygrometers were used. One was placed outside the polyhouse under the shadow of the house. The second was placed inside the polyhouse near the central column. The second sensor was protected from the direct incidence of the radiation
- The wind velocity was measured at different locations at different time intervals

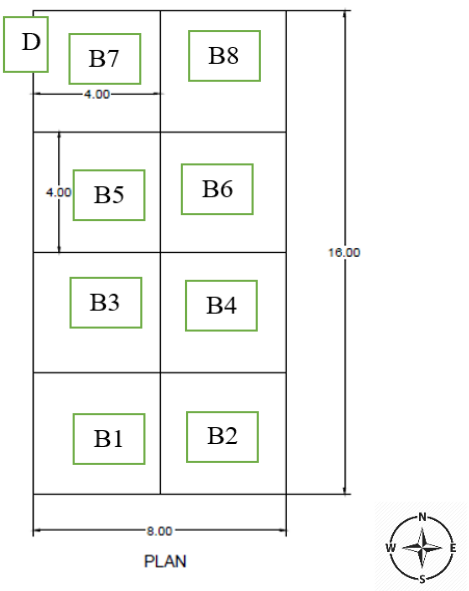


Figure 9. 3: Locations inside polyhouse from where data was collected (Balapur, Vikramgad site) *D – door location*

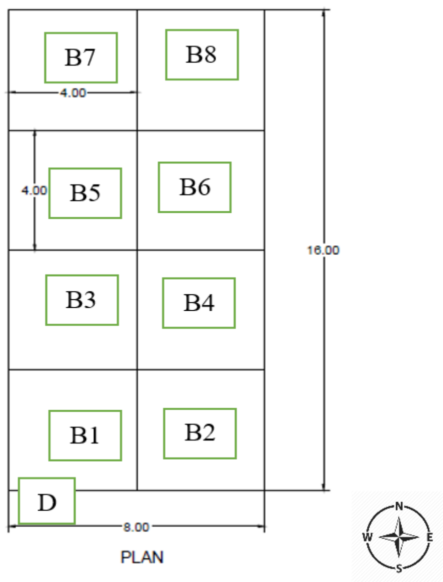


Figure 9. 4: Locations inside polyhouse from where data was collected (Ramkhind, JAwhar site) *D – door location*

- The spatial temperatures were measured using the temperature meter inside the anemometer
- Figures 9.3 and 9.4 shows the different Bays from B1 to B8 used to collect the spatial data of temperature and humidity
- Wind speed data were collected near the insect-proof net from inside and outside the polyhouse

9.3 Results and conclusions on microclimate analysis

Data was collected from 2 sites, Site 1 = Ramkhind Site (Polyhouse with top vent area closed),

Site 2 = Balapur (Polyhouse with top vent area open)

9.3.1 Analysis of the data for Ramkhind site – (Polyhouse with vent area closed)

The following table shows the variation in the temperature inside and outside the polyhouse for the data collected on 10th March 2021. This table also shows the variation in the values for humidity. The maximum difference between inside and outside temperature is found as 2.8^{0}C. The maximum and minimum temperatures inside the polyhouse were 40.1 ^{0}C and 29.9 ^{0}C, respectively. The maximum difference in humidity is found to be 3%.

Table 9. 2: Temperature and Humidity variation (inside and outside of polyhouse) throughout the day for Ramkhind Site (Polyhouse with Top vent is closed)

Sr. No	Time	Temperature (^{0}C)			Humidity (Relative in %)		
	Time	T inside	T outside	Temperature Difference	Humidity Inside	Humidity Outside	Humidity difference
1	09:12	29.9	28.9	1	33	34	1
2	09:27	31	28.5	2.5	31	32	1
3	09:38	31.8	29.8	2	31	32	1
4	09:56	33.8	31.5	2.3	30	31	1
5	10:12	34.7	32.9	1.8	29	30	1
6	10:38	35.9	33.2	2.7	29	30	1
7	10:51	36.7	33.9	2.8	28	29	1
8	11:04	37	35.4	1.6	28	30	2
9	11:25	37.8	36.3	1.5	27	29	2
10	11:38	38.3	36.9	1.4	27	28	1
11	11:50	38.4	37.2	1.2	27	28	1
12	12:01	38.9	37.6	1.3	26	28	2
13	12:20	39.5	38	1.5	27	27	0
14	12:51	39.3	37.8	1.5	26	27	1
15	13:35	39.8	38.1	1.7	26	27	1
16	14:01	39.8	38.6	1.2	26	27	1
17	14:29	39.7	38.4	1.3	26	26	0

18	15:02	39.7	38.2	1.5	26	26	0
19	15:28	40.1	38.2	1.9	25	28	3
20	16:02	39.1	37.9	1.2	26	28	2
21	16:16	38.5	37.8	0.7	26	29	3
22	16:31	37.8	37.2	0.6	27	28	1
23	16:45	37.7	36.6	1.1	27	29	2
	Max	**40.1**	**38.6**		**33**	**34**	1
	Min	**29.9**	**28.5**		**25**	**26**	1

After understanding the temperature and humidity variation w.r.t time and comparing with the outside atmosphere, now let's look into the spatial variation in the temperature inside the polyhouse.

After 4 PM on 10th March 2021, data for spatial temperature variation was recorded. All the temperatures were recorded around 1m in height from the ground. To consider the response of thermocouple towards temperature variation, we recorded the temperatures by keeping the sensor for 3 to 4 minutes at the same location. Following figure 9.5 shows the variation in temperature at different positions inside the polyhouse –

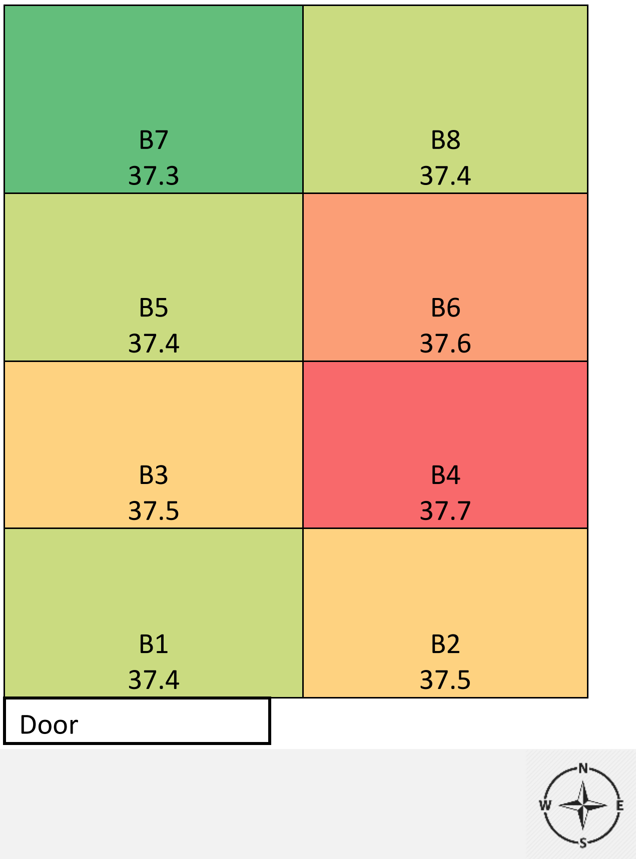


Figure 9. 5: Spatial Temperature Variation inside the polyhouse at Ramkhind site (Polyhouse with top vent closed)

Based on the external conditions along with the location of the door, drip tank, ventilation, etc., temperature variation happens. A few of the reasons for spatial temperature variation at this site (polyhouse with top vent closed) are –

- The door is located at bay B1. This will help in making more ventilation intermittently compared to other places.
- The minimum temperature observed at bay B7 is having the drip tank installation just outside, and it gets more discharge of water being 1^{st} one connected to the drip line.
- Most of the time, air flows from the west direction, and therefore the maximum temperature is not observed bays on the left (west side).
- While measuring the wind velocities on east side walls, wind in the outward direction was measured.

Wind speed measurements for Ramkhind site (Polyhouse with top vent closed):

We have measured the wind velocities at different locations of polyhouse using a Digital Anemometer. To give the feel of different wind speeds in m/s, we have measured the wind speed of the ceiling fan at a distance of 4ft from the fan.

The location of measuring Vane type probe – towards the end of ceiling fan blades. And axis of the vane probe was parallel to the axis of the fan

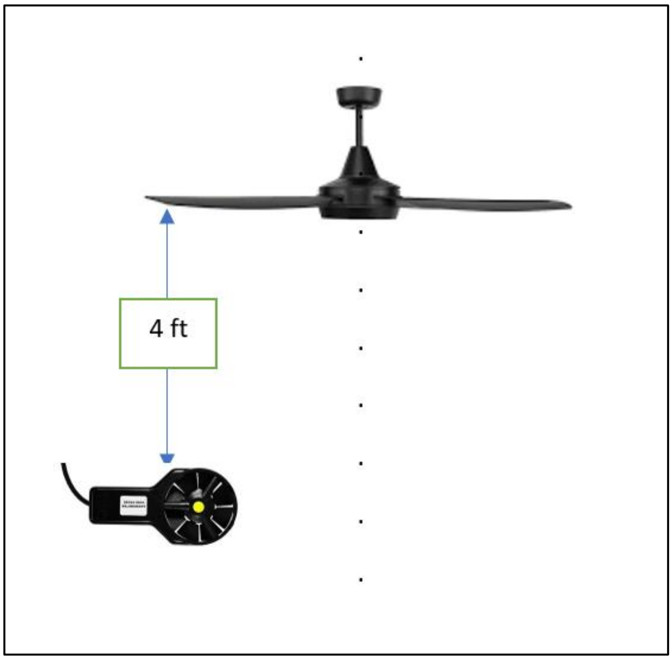


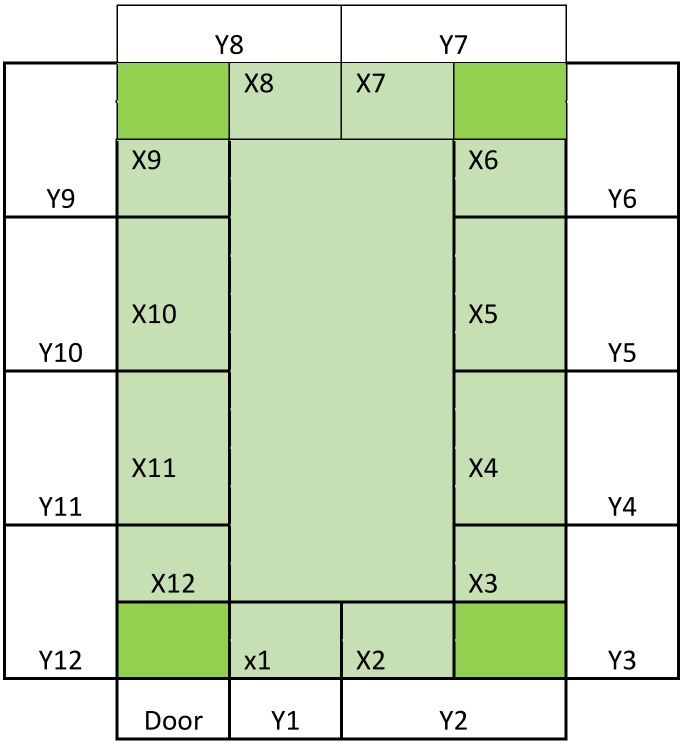
Figure 9. 6: Location of the wind speed measuring probe and ceiling fan

Table 9. 3: Wind speed in m/s for different levels of ceiling fan speeds

Sr. No	**Fan Speed (level as per regulator)**	**Wind speed measured by Anemometer**
1	Level 1	<0.4 m/s (not recorded by anemometer)
2	Level 2	0.5 to 0.6 m/s
3	Level 3	1.5 m/s
4	Level 4	2.6 m/s

Measurements were done by ensuring no effect of external wind flow.

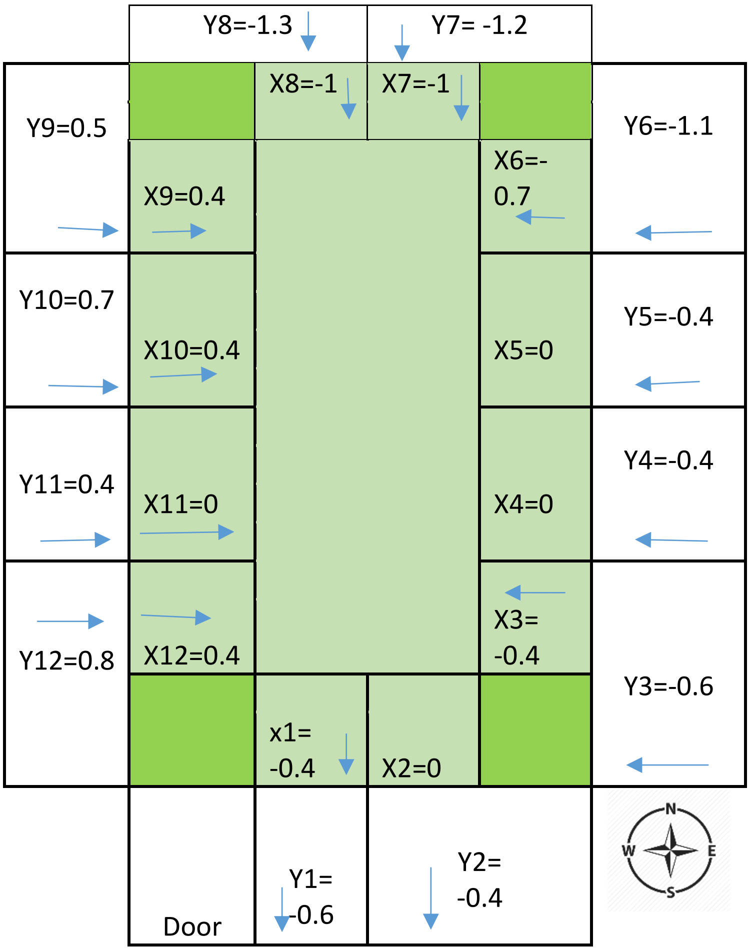
Wind speed was measured for every wall from inside and outside the polyhouse at 0.5 to 2 ft from the wall.



X- Measurement location inside the polyhouse, Y- Measurement location outside the polyhouse

Figure 9. 7: Locations near walls where wind speeds (m/s) were measured for Ramkhind Site (Polyhouse with top vent closed)

Figure 9.6 shows the locations outside and inside the polyhouse for which wind speed data was recorded. The data obtained for wind speed using a digital anemometer is visualised as follows-



X- Measurement location inside the polyhouse, Y- Measurement location outside the polyhouse

Figure 9. 7: Data for wind speed (m/s) for 1st cycle of data collection wind speeds were measured for Ramkhind Site (polyhouse with top vent closed)

AS shown in figure 9.7, wind speed is represented near the walls of the polyhouse. Following sign conventions will be helpful to understand the wind directions

1. The wind coming from the west is +ve
2. The Wind flowing towards the west is -ve
3. The wind coming from the north is -ve
4. The Wind flowing towards the north is +ve

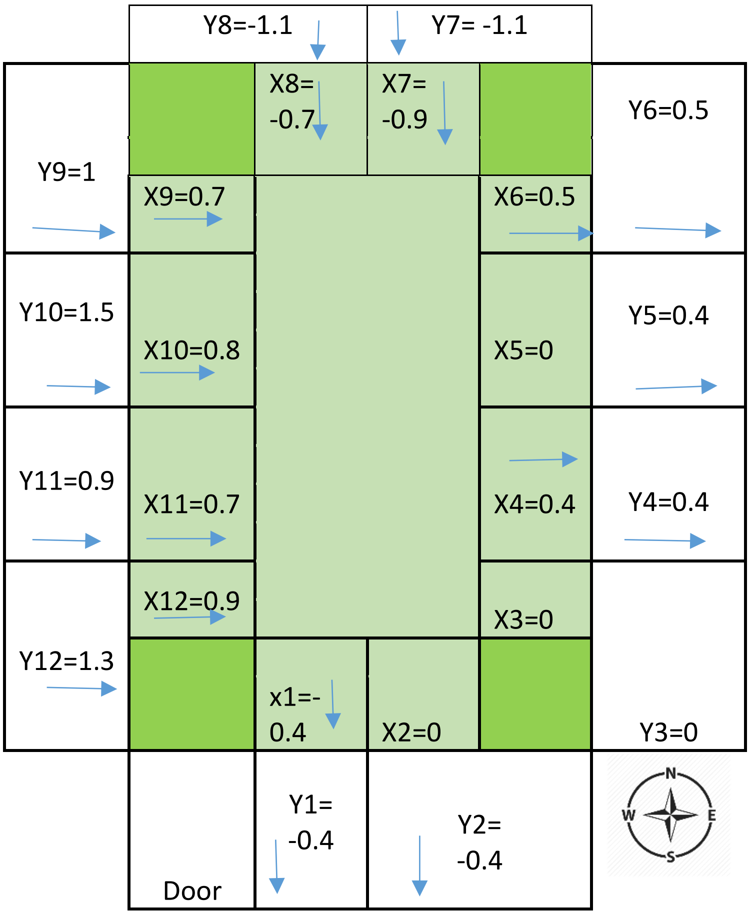
From 1st cycle of wind speed data, it is clear that the exhaust of the wind is happening through the wall on the south end. The 1st cycle data was collected between 12 PM and 1 PM on 10th march 2021. The internal pressure created on the wall was visually observed as shown in the figure below –

Figure 9. 8: Internal wind pressure on Insect-proof net of the walls

The insect-proof net on the walls with external pressure was observed visually as shown in figure 9.8.

Figure 9. 9: External wind pressure on the insect-proof net of the walls

The second cycle of wind speed measurements was conducted between 3 PM to 4 PM on 10th March 2021. Figure 9.10 shows the wind is majorly coming from the west side, and after entering the polyhouse, it is also leaving with 0.4 to 0.6 m/s of velocity.



X- Measurement location inside the polyhouse, Y- Measurement location outside the polyhouse

Figure 9. 10: Data for wind speed for 2nd cycle of data collection wind speeds were measured for Ramkhind Site (Polyhouse with top vent closed)

9.3.2 Analysis of the data for Site 2 (Balapur – Polyhouse with top-vent open)

All the data for the Balapur site was measured on 11th March 2021. The inside and outside temperature & humidity variation w.r.t. time and space is measured and tabulated in table 9.2. This table indicates the maximum temperature difference between inside and outside the polyhouse is 1.6^{0}C. The maximum temperature observed inside the polyhouse is 39.8^{0}C

Table 9. 4: Temperature and Humidity data collected from polyhouse at Balapur (Polyhouse with top vent open)

Sr. No	Time	Temperature			Humidity	
	Time	T Inside	T Outside	Temperature difference (Inside-outside)	Humidity Inside	Humidity Outside
1	11:53	37.3	37.3	0	29	29
2	12:02	38	37.3	0.7	28	29
3	12:14	38.1	37.1	1	28	29
4	12:26	38.3	37.3	1	28	29
5	12:37	38.7	37.9	0.8	28	29
6	12:44	39	38.1	0.9	27	28
7	13:00	39.4	38.5	0.9	27	28
8	13:11	39.4	38.5	0.9	27	29
9	13:22	39.5	38.5	1	27	29
10	13:34	39.7	38.6	1.1	27	29
11	13:45	39.8	38.5	1.3	27	29
12	13:54	39.8	38.2	1.6	27	29
13	14:06	39.5	38.3	1.2	27	29
14	14:24	39.3	38.4	0.9	27	30
	Max	**39.8**	**38.6**	1.2	**29**	**30**
	Min	**37.3**	**37.1**	0.2	**27**	**28**

Following figure 9.11 shows the spatial temperature variation inside the polyhouse at the Balapur location. These temperatures were recorded after 4 PM on 11th March 2021.

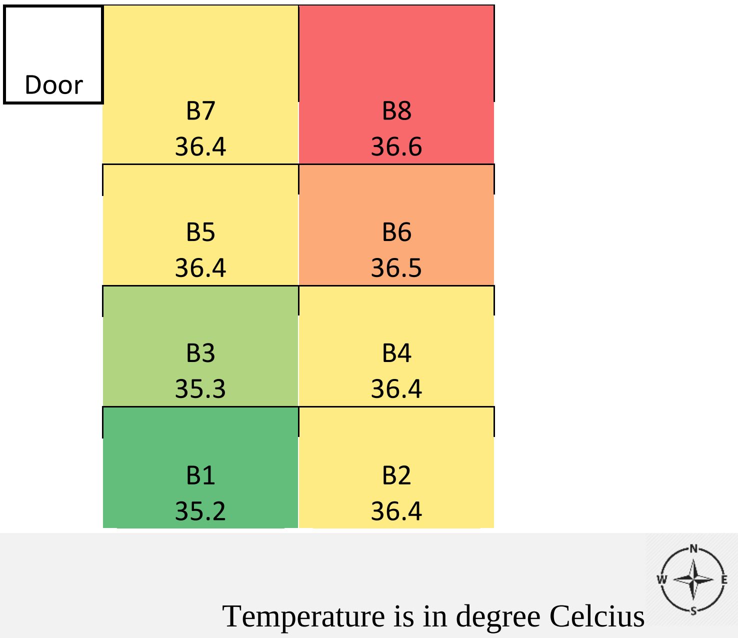


Figure 9. 11:Spatial temperature variation in the polyhouse at Balapur site (Polyhouse with top vent open)

The possible reasons for variation in temperatures at different bays inside polyhouse –

- The shadow of the tree and house near the polyhouse covers the part of bays – B1 and B2. This may be the reason for low temperatures at B1 and B2
- Maximum irrigation happens near B1 as it is 1st bay connected to drip lines
- No inlet velocity was measured from the east due to this, and no shading of external elements makes bays B6 and B8 hotter than other

Daily minimum and maximum temperature data for polyhouse at Balapur is mentioned in the following table -

Table 9. 5: Minimum and Maximum temperatures recorded inside the polyhouse for Polyhouse with Top vent open

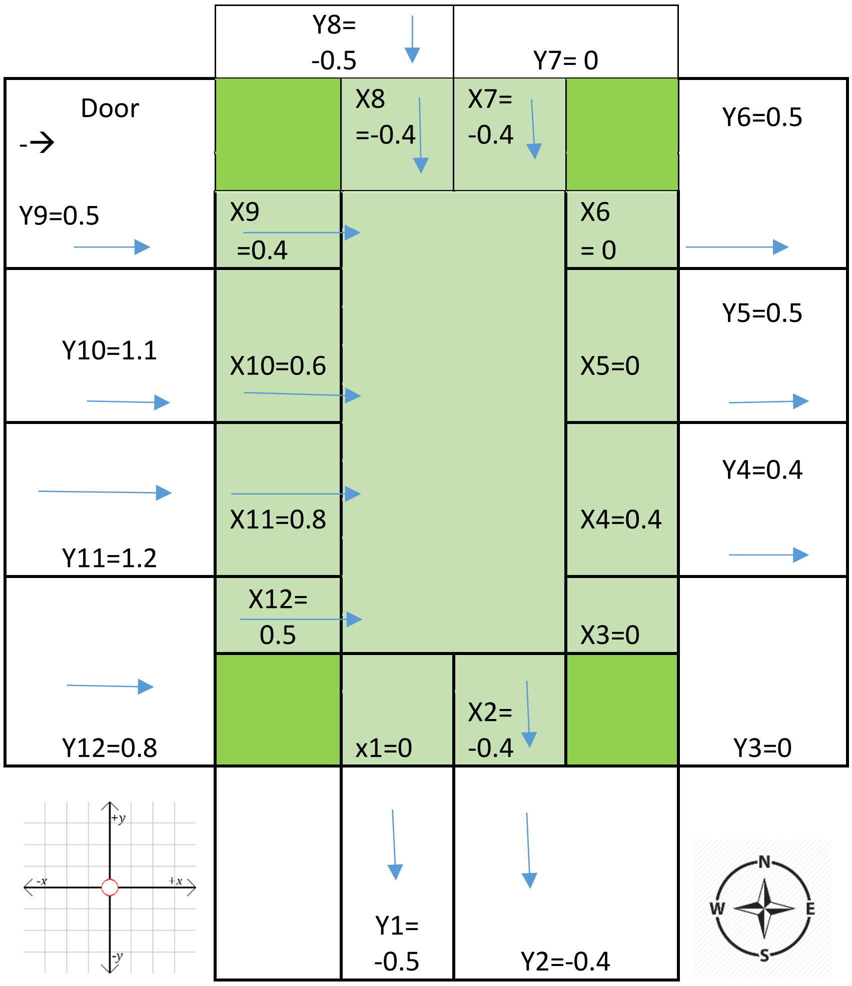
	The temperature in degree Celcius	
Date	T min	T max
12-03-2021	21.1	39.9
13-03-2021	21	39.8
14-03-2021	21.1	40.1
15-03-2021	21.5	40.3
16-03-2021	20.7	39.7
17-03-2021	21.5	40.2
18-03-2021	22.3	40.6
19-03-2021	19.9	39.5

The HTC-1 instrument provides an option of recording the data for minimum and maximum values in the past 24 hrs. Based on this feature above values were recorded.

Wind speed measurements for Balapur site

Similar to Ramkhind location (Polyhouse with top vent closed), wind speeds were measured for Balapur location (Polyhouse with top vent open) and mentioned in figure 9.12

All the values of wind speed in figure 9.12 are in m/s. The wind was entering the structure from the west, south, and north walls of the polyhouse, and exhaust is observed at the east wall of the polyhouse.



X- Measurement location inside the polyhouse, Y- Measurement location outside the polyhouse

Figure 9. 12: Locations near walls where wind speeds (m/s) were measured for Balapur Site (Polyhouse with top vent open)

9.4 Conclusions from Temperature, Humidity, and Wind velocity data

The maximum temperature difference between the inside and outside climate of the polyhouse is observed at the Ramkhind site. The closing of vent space at the top using the insect-proof net at the Ramkhind site might be the reason for the high-temperature difference than that of the Balapur site. The Anemometer was unable to record wind speeds below 0.4 m/s; hence, we tried simulating the CFD model for bamboo polyhouse in the next chapter. The spatial variation in temperature and ventilation will give different yields in different parts of the polyhouse. To minimize the temperature inside the polyhouse, the use of evapotranspiration cooling (by cultivating some plants with more evapotranspiration) is recommended by IS 14485: 1998. The IS 14485: 1998 code also recommends the use of exhaust fans for ventilation.

Chapter 10

CFD analysis of the microclimate in the Bamboo Polyhouse

After analyzing the structure against loading conditions and understanding the temperature variation spatially and temporally. It is also essential to understand the performance of the naturally ventilated polyhouse using software simulation.

This small chapter covers the design, modeling, and simulation of the Naturally ventilated polyhouse using CFD in ANSYS.

10.1 Developing a polyhouse geometry in ANSYS

The polyhouse consists of a top vent, sidewalls, top roof, etc. It is challenging in any software to design for the insect-proof net of 40 mesh size and diameter of every hole = 0.26 mm.

Insect-proof net behaves as a porous body and provides viscous resistance to airflow. The properties of the insect-proof net against the airflow are not known. It is also difficult to make geometry for an insect-proof net in Ansys.

To overcome this challenge, we developed a small 2mm * 2 mm area and then developed the holes on it as specified for an insect-proof net. This body is enclosed in a fluid domain, and the air is passed over it with different velocities, in this case finding the pressure difference created due to porous media in the question. This can be done using Ergun’s equation or simulating the ANSYS model to get the empirical equation, which will be specific to the test specimen.

$$\Delta p/\,L \;=\; \frac{150\,\mu\,(1-\,\varepsilon)^{\,2}}{\varepsilon^3\,d^2}\,u \;+\; \frac{1.75\rho\,(1-\,\varepsilon)}{\varepsilon^3\,d\emptyset}\,u^2 \;\ldots\ldots\ldots\ldots\ldots\ldots.\,(10.1)$$

Variables of the above equation are-

$\Delta p/\,L$	Pressure drop per unit length
μ	Dynamic Viscosity
ε	Void Fraction or Porosity
d	Diameter of void
ρ	Density of fluid

10.1.1 Simulation of prototype porous body

The equation 10.1 can be written as

$$\frac{\Delta p}{L} = C1 * u + C2 * u^2 \ldots\ldots\ldots\ldots..(10.2)$$

Our objective is to calculate the C1 and C2 values and then to use them in Ansys fluent. The term ‘u’ in the above equation is wind velocity.

Initially, we developed a geometry for an insect-proof net of 40 mesh size, 0.26mm hole diameter, and prototype dimension of 2mm*2mm.

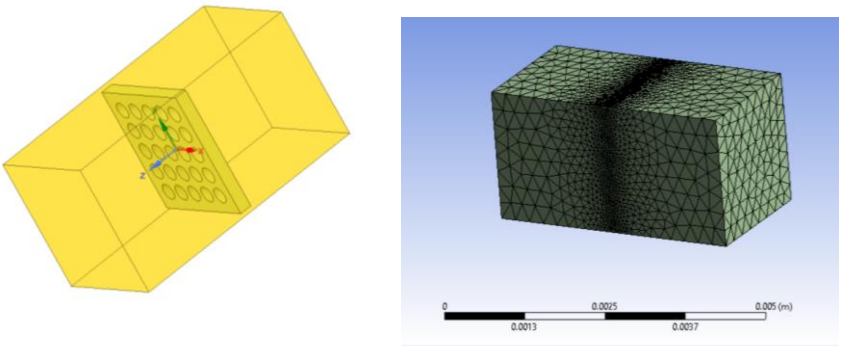


Figure 10. 1: Geometry and Meshing for the prototype insect-proof net in ANSYS

The geometry and Meshing of the prototype is shown in figure 10.1

After meshing, the setup was made in CFD fluent in calculating the pressure difference. Here we have only considered wind velocity as the reason for pressure difference and temperature in neglected. The turbulent model was selected, and inlet and outlets were assigned as shown in figure 10.2 –

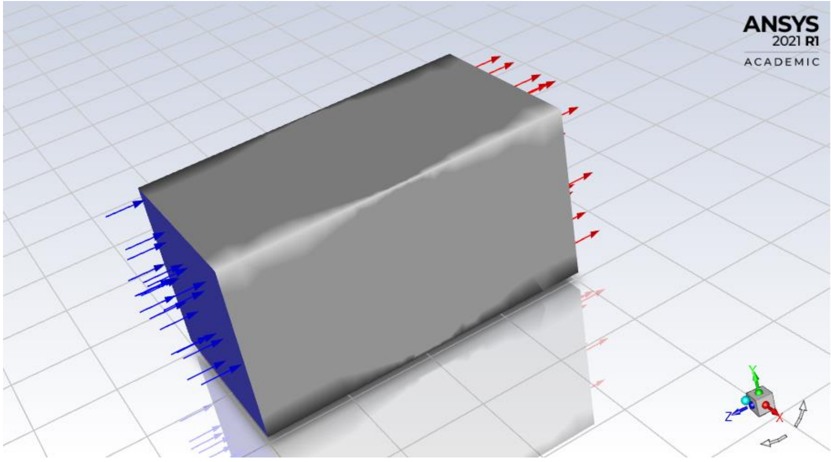


Figure 10. 2: Fluent setup for Prototype simulation

Fluid (Air) will flow through the square pipe (fluid body) at the middle the prototype of the insect-proof net is place. This will create an obstacle to the flow of air, and pressure difference will happen between the inlet and outlet section.

10.1.2 Results and Analysis of prototype simulation to generate an empirical equation

After developing the model, in setup, initial boundary conditions were set-up by defining the inlet velocity. The model was initialized using the *hybrid initialization* method. The model was simulated for 200 iterations. The model was simulated 19 times with inlet velocity ranging from 0.5 m/s to 5m/s with a step size of 0.25 m/s.

Following are the pressure difference (drop) values obtained after the simulation

Table 10. 1: Pressure drop values for different wind speeds

Sr. No	Inlet velocity	Pressure drop (PD) Pa	PD/length Pa/m
1	0.5	6.287	1571.75
2	0.7	10.01	2502.5
3	1	16.44	4110
4	1.25	22.65	5662.5
5	1.5	29.61	7402.5
6	1.75	37.25	9312.5
7	2	45.68	11420
8	2.25	54.498	13624.5
9	2.5	64.22	16055
10	2.75	74.48	18620
11	3	85.41	21352.5
12	3.25	96.04	24010
13	3.5	109.06	27265
14	3.75	121.74	30435
15	4	135.06	33765
16	4.25	148.98	37245
17	4.5	163.41	40852.5
18	4.75	178.86	44715
19	5	194.1	48525

This data is used to fit a curve in MINITAB to get an empirical equation as shown in figure 10.3 -

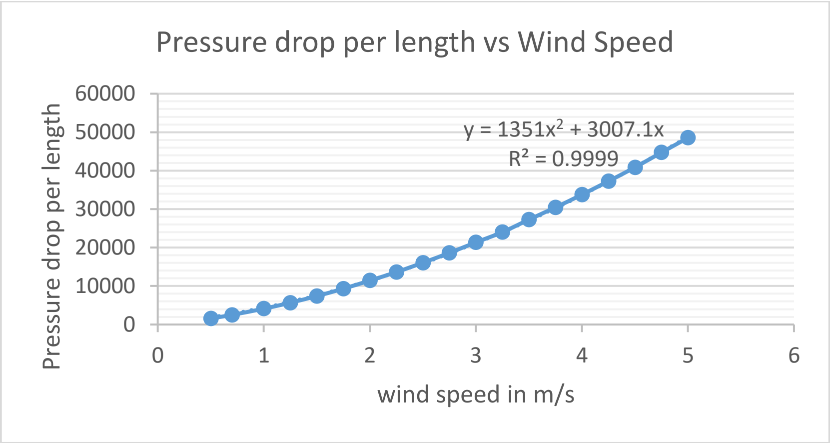


Figure 10. 3: Curve fitting to get an empirical equation in MINITAB 18

The empirical equation obtained from curve fitting is –

DP/L = 3007.1 Vin + 1351 Vin^2 ……………………………………………(10.3)

The significant curve fitting is observed as R-square = 99.99%, and P-value = zero.

Comparing equation 10.2 and equation 10.3, we get

C1 = 3007.1

C2 = 1351

The following figure 10.4 shows the resistance to flow offered by a prototype of the insect-proof net –

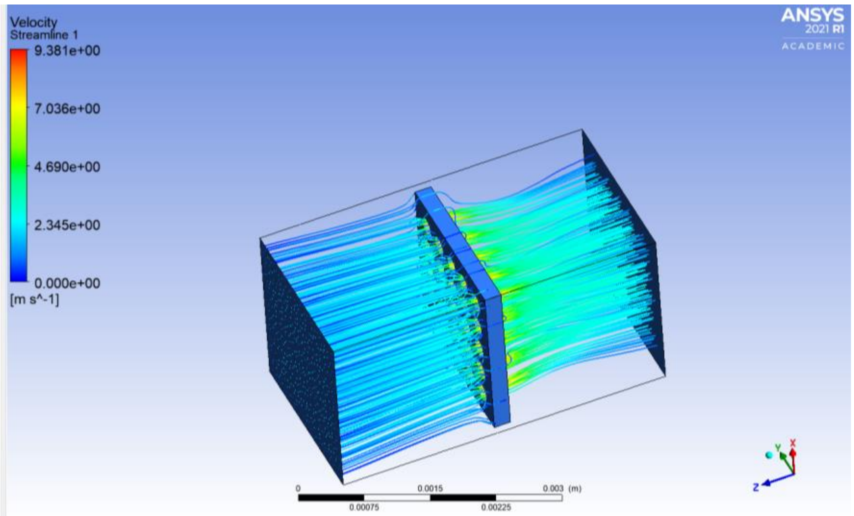


Figure 10. 4: 3D streamline showing a behavior of the insect-proof net prototype

The obtained C1 and C2 values will be used in a fluent model setup before simulating for the polyhouse.

10.2 Simulation of the polyhouse model

After getting the empirical constants for the viscous sidewalls, the geometry of the polyhouse was developed. Around the solid and viscous body of the polyhouse and inside the polyhouse fluid body was developed to give inlet velocities. The following figure shows the geometry and meshing of the polyhouse in ANSYS –

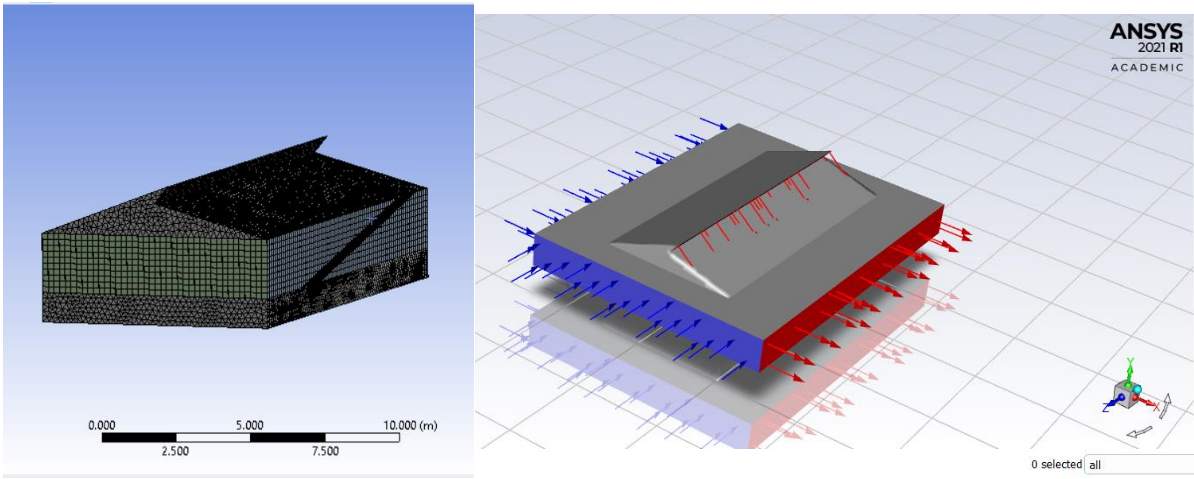


Figure 10. 5: left image – mesh formation and the right image –fluid domain surrounding the polyhouse

After assigning all the values model was simulated with 200 iterations, and the following velocity profile was generated.

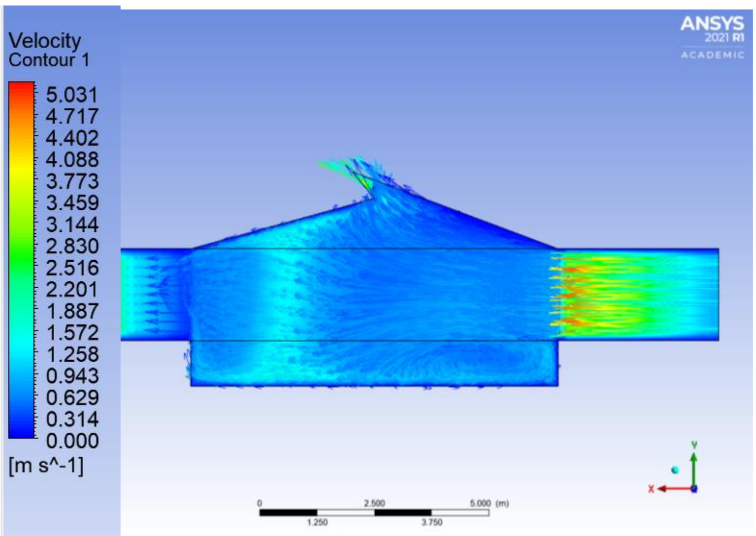


Figure 10. 6: velocity profile generated in CFD when inlet velocity is 2.5m/s

The above figure is showing the contours for velocities inside the polyhouse at a central cross-section. Most of the simulated velocities near the boundaries are matching with the measured values (in the range of 0.4 to 0.9m/s). The simulated velocity at the location 2m inside the left wall (Ref. figure 10.6) shows a higher estimate of the velocity. The top view of the velocity contour shows the wind's restrictions due to the insect-proof net's sidewalls (Ref. Figure 10.7). As shown in the top view velocity of restricted wind is increased near the end along the length. Similar observations were made while measuring the wind velocity on the field.

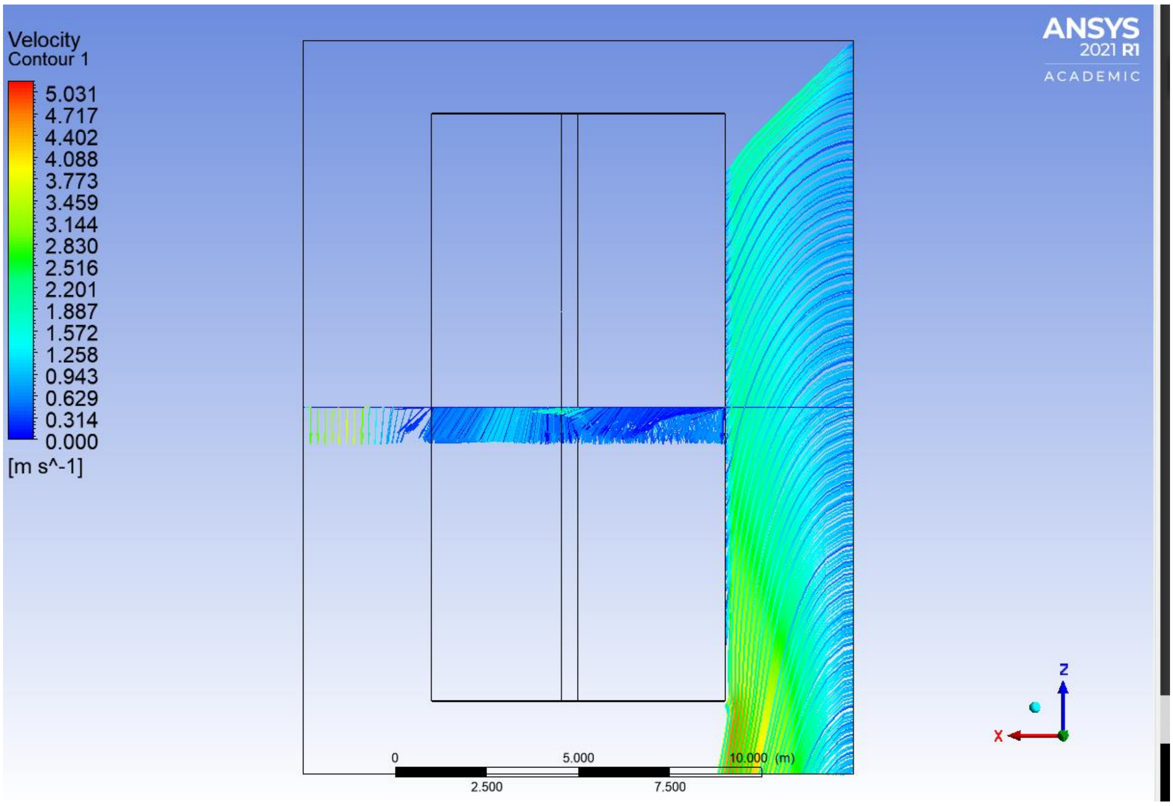


Figure 10. 7: Top view of the velocity contour developed in CFD

In this chapter, we have seen that the ventilation of the polyhouse depends on the shading material used along the walls. The use of an insect-proof net provides only 13 to 14 % of the opening area. Hence this can be compared with the shed net of 50% opening area.

Chapter 11

CULTIVATION UNDER BAMBOO-POLYHOUSE

After the design, analysis, and construction of the bamboo-polyhouse, we did the activities to start the cultivation inside the polyhouse. This chapter covers the crop planning and activities covered and the current status of polyhouse cultivation at both locations.

11.1 Soil preparation and Bed preparation

After finishing the construction of the polyhouse, soil preparation was done. In the area of 128 sqm, 20 beds were made. The dimensions of the beds are as follows – Length = 7.5m, width = 0.45m, and height = 0.15m. While making the beds, the following bio-organic composts were used –

1. Neem powder
2. Sterameal
3. Compost from Cow-Dunk (Shen-Khat)

After raising half of the total height, the compost was supplied over the bed.

The following figure shows the beds prepared at both the sites –

Figure 11. 1: Beds prepared at a) Balapur site b) Ramkhind site of polyhouse

30 cm gap was left between two beds. Therefore total area lost in free space is around 40 sqm.

To utilize this area, we are planning to develop a verticle farming kit using waste drums or casing pipes. The drip system installation was done after the bed preparation.

11.2 Crop planning for polyhouse

The major objective of the bamboo polyhouse is to provide year-round nutritional security. Therefore crop plan is made such that it will cover a diverse variety of vegetables. After finishing all the activities inside the polyhouse, we have cultivated the following vegetables in the polyhouse –

- Leafy vegetables – Spinach, Amaranth leaves
- French beans, local beans variety
- Tomato, brinjal
- Chili, Capsicum
- Carrot, Radish

These are the vegetables currently under cultivation inside the polyhouse. Following figure 11.2 shows the status of vegetables grown in polyhouse at Balapur site on 20th March 2021–

Figure 11. 2: vegetable cultivation under the polyhouse at Balapur site

The location and sequence of the crops is decided with the consultation of an agricultural expert from BAIF.

7.3 Operations and Management for bamboo Polyhouse

After cultivation inside the polyhouse farmer is expected to keep records of different activities and observations made. The basic management activities for a farmer includes –

- Irrigating the land
- Making Bio-Organic manure
- Removing weeds
- To observe the plant leaves to check pest attacks
- Record the observations

To irrigate the land inside the polyhouse, a gravity-based drip irrigation unit is installed. Still, if farmers wish, they can join the pump water supply to drip lines, which also benefits the micro-sprinklers. Farmer at Balapur location irrigates the land for 2 to 3 hours at night (3 AM to 6 AM). The farmer from the Ramkhind site irrigates the land two times (in the morning and evening) for a total of 2 to 3 hours. The tank discharges in around 2 to 3 hrs of continuous drip supply.

After irrigation, organic manure preparation is the big task. As the farmer is trained to make organic manures such as Shen-khat, liquid Jivamrut, and Enzymes for the quick decomposition of cow-dunk, etc. The methods of organic manure preparation are attached in appendix B.

One record-keeping book is provided to the farmer. He is expected to write about irrigation water supplied – method and duration, name of manure/fertilizer supplied, quantity, and supply method. Also, the important thing to record is the quantity of vegetables produced from the polyhouse. One of the observations made by the farmer – fruiting for one capsicum tree and flowering for the others as shown in the figure below (date – 3rd march 2021)–

Figure 11. 3: Capsicum fruit observed by the farmer from the Balapur site

Chapter 12

TECHNO ECONOMICS OF THE BAMBOO POLYHOUSE

After understanding the structural feasibility of the bamboo polyhouse, we tried to find the financial and social feasibility of the polyhouse. To check the feasibility of the bamboo polyhouse, we have tried to compare it with the conventional GI polyhouse. The cost of the components is taken from the nearby fabricators through quotations.

Table 12. 1:: Expected life of the few standard components in the polyhouse (primary data from experts)

Sr. no.	**Component**	**Expected Minimum Life in years**
1	Polythene Film	4 to 5 (3 years Guarantee by the company)
2	Shed net and G-Fab sheet	4 (3 years Guarantee by the company)
3	Bamboo Structure	4 to 5 years for non-treated bamboos 10 – 15 years for treated bamboos
4	Foundation	10 - 20
5	Drip lines	4
6	spring	5
7	Profile for fixing the sheet	10

These life spans helped to find the life cycle costs and the annualized life cycle costs. This ALCC helps in comparing the different technologies having different life span.

12.1 Costs involved in the construction of Bamboo Polyhouse

The following table shows the different components and the respective costs of those components. The fixed cost for the bamboo polyhouse is coming around 90,165 Rs. And the variable cost per year is around – 8,850 Rs/ year

Table 12. 2: : Fixed costs involved in building a bamboo polyhouse

Type of cost	**Details**	**Cost in Rs**
Fixed Costs [1]	Treated Bamboos with transportation	30,348
	Polyhouse materials (including shed net, polyfilm, fixtures)	35,000
	Labour for workshop	7,500
	Erection Labour charges	5,000
	Transportation	5,000
	Drip Irrigation (5000 tank +2182drip+135sprinklers)	7,317
TOTAL		**90,165 Rs**

Table 12. 3: Variable costs for maintaining the Nutri-Garden with polyhouse

Type of cost	**Details**	**Cost in Rs**
Variable costs [2]	Seed+saplings	1000
	Manure	3850
	Maintenance	2000
	miscellaneous	2000
TOTAL		**8850 Rs/year**

Cost per square meter of the polyhouse with drip = 704.41 Rs/Sq.m

Cost per square meter of the polyhouse without drip = 647.25 Rs/Sq.m

12.2 Comparing the bamboo polyhouse with conventional polyhouse

The following table compares the costs involved in building the polyhouse with a bamboo structure and with a conventional structure. The ALCC for the polyhouse with non-treated bamboo came to the minimum, but there is a high risk of failure due to water contamination, getting affected by an insect-like termite and stem borer, etc.

Table 12. 4: Comparing the polyhouse with bamboo structure with conventional polyhouse

Entity	**Polyhouse with treated Bamboo**	**Polyhouse with non-treated bamboos**	**Polyhouse with steel/GI structure 1**	**Polyhouse with steel/GI structure 2**
Cost	90,165 Rs/128sqm	69,317 Rs/128sqm	1.88 lac Rs / 100sqm	2.77 lac Rs/ 100sq.m
Cost per sqm	735.93 Rs/Sq.m	585.93 Rs/Sq.m	1880 Rs/Sq.m	2770 Rs/Sq.m
Life of the structure	5-10 years	5 years	15-20 years	20 years
Life of the poly film and shed net	4-5 year	4-5 years	4-5 years	4-5 years
Annualised LCC (Rs)	15,382 Rs (10 yr) 18,460 Rs (5yr life)	13,837 Rs	24,389 Rs	28,927 Rs
Risk factor	Less risk of getting affected by stem borer and water	More risk of getting affected by borer, water	No risk from termite & borer, risk of failure due to rust	No risk from insect-like borer, minimum risk of failure due to rust

Based on the structural life of the polyhouse and the life of other materials, ALCC is calculated. We found a significant difference in ALCC of treated Bamboo Polyhouse – 15,382 Rs and ALCC of conventional polyhouse – 28,927 Rs

12.3 Return on investment

The warranty of the polyhouse is given for five years. The bamboo expert tells the life of the treated bamboo for more than ten years.

To calculate the return on investment of 90,165 Rs. we need the productivity data. As the first crop cycle is not completed, we have used the literature indicating the production of specific vegetables from polyhouse. The average market rate is considered to calculate the profit. Assuming a minimum of four crops are grown inside polyhouse – tomato, brinjal, cucumber, and capsicum. Now dividing the area of polyhouse = 128sqm in four parts → 32 sqm/crop. Based on these assumptions following calculations are made –

Table 12. 5: Gross Income from the excess produced from bamboo polyhouse

Sr. No.	**Crop Name**	**Productivity (Annual)**	**Total production from polyhouse**	**Actually sold quantity = 60% of the production**	**Marker Selling price Rs/Kg**	**Total Income in Rs**
1	Tomato	**16 Kg/sqm** Source –(Firake et al., 2014) *minimum value*	16kg/sqm*32sqm = 512kg	308kg	30 Rs/Kg	9240Rs
2	Brinjal	3.5 Kg/ sqm in open cultivation, assuming **10kg/sqm** in polyhouse	10kg/sqm*32sqm =320kg	192Kg	25 Rs/Kg	4800Rs
3	Capsicum	Assuming **10 Kg/sqm**	10Kg/sqm*32sqm = 320Kg	192 Kg	40 Rs/Kg	7680Rs
4	Cucumber	6 kg / sqm in open cultivation, Assuming **17 kg/sqm** in polyhouse	17 kg/sqm*32sqm = 544kg	326 Kg	30 Rs/Kg	9780Rs
	Total		1696kg	1090kg		
Total Income from selling the surplus produce from Polyhouse						**31,500Rs**

As per WHO, a person should eat 400 grams of vegetables per day. Assuming five people in a house of the farmer, therefore 2 kg vegetables will be required per day. Computing the vegetable requirements for a year, a family requires = 365 days * 2kg/day = 730 kg of vegetables per year.

Production from the polyhouse for a year is = 1696 kg (Ref. Table 10.5). Therefore, the yearly vegetable requirements of the family are 43% of the annual production from polyhouse. Assuming 60% of the produced is sold in the market.

We have 31,500 Rs as gross income from polyhouse assuming farmers are using the self-made organic resources for cultivation, assuming the cost for seeds + saplings is below 1000 Rs. Based on the assumptions, the payback period for this bamboo polyhouse will be of 3 years.

To reduce the **payback period of 3 years**. We should focus on reducing the cost of polyhouse or designing a larger structure with less cost.

Chapter 13

CONCLUSIONS

To tackle malnutrition in India, different interventions are made. The practice of Nutr-Garden is one of these interventions. Various government and non-government organizations help rural households to build and maintain Nutri-gardens. In the first phase of this project, based on the qualitative and quantitative survey of Nutri-Garden growers and field visits, we found three major constraints in getting year-round production through Nutri-Gardens. Such as – 1) Excessive water scarcity in summer, 2) heavy rainfall in monsoon, 3) no protection against free animals/cattle.

After understanding the problem, we decided to demonstrate the protected cultivation using bamboo polyhuse for Nutri-Garden as a low initial cost design. The FGD between IITB, BAIF, and Annamrita stakeholders helped identify the farmers' interest in this model and select the farmers to demonstrate the model. The site selection was made based on the guidelines of Indian standards. With the help of a polyhouse construction company design and development of the bamboo, polyhouse is done. Based on the calculations presented in the report bamboo polyhouse proposed was found to be safe against wind velocity of 44m/s as per ETAB analysis.

After the design and analysis, two bamboo polyhouses were constructed using treated bamboo and joinery methods by following the Bamboo IS code guidelines. The spatial and temporal variation in temperature and humidity is recorded using HTC-1: thermo-hygrometer. The maximum temperature difference between inside and outside polyhouse was found to be 1.6 for the Balapur site (Site with top vent open) and 2.8 for Ramkhind site (Site with top vent closed). The maximum temperature reached inside Ramkhind polyhouse (polyhouse with top vent closed) is 40.1^0C. The special variation in temperature is also mapped in chapter 8.

The wind speed was measured with a digital anemometer. The maximum wind velocity measured inside the polyhouse is of 1m/s. Zero wind speed was captured away from walls and inside the polyhouse. The flow of wind from inside to outside shown the ventilation is happening with an exhaust wind speed of 0.4 to 0.6 m/s. To check the performance of the naturally-ventilated polyhouse, CFD simulation was performed. The CFD results shown in the contour diagram gives the wind speeds at different locations of the polyhouse demonstrating acceptable natural ventilation.

After the construction of the polyhouse, other cultivation activities were initiated. Crop planning was done based on the objective of delivering a diverse variety of vegetables. Chemical-free cultivation methods are adopted for this polyhouse. Gravity-based drip irrigation units are also installed in the polyhouse for optimal water-consumption by the selected plants.

The constructed polyhouse costs one-third of the traditional GI polyhouse. The cost of a bamboo polyhouse, including the drip irrigation, worked to be Rs. 90,000 which is expected to come down with further "stram-lining". Presuming the average yield from the polyhouse (1700 Kg/annum), the payback period of 3 years is computed. The findings of this project will help rural households to get year-round nutrition security, and it will also help in earning some income. This research can be used as a base for for possible scale-out for low-cost bamboo polyhouse structure designs that can be integrated in any part of India.

13.1 Limitations of the project

The project analyzes the structure of bamboo polyhouse in ETAB based on the physical and mechanical properties of *Dendrocalamus Stocksii.* These properties are not available in the Indian standards code for bamboo, which is modified in 2018 (IS 15912: 2018). This study has not performed any structural tests like compression tests and tensile tests using a universal testing machine for bamboos used in the structure. The values of different properties are taken from the literature survey. Some properties are assumed to be equal to the *Dendrocalamus Strictus.* Due to time and money constraints, only two models of Bamboo polyhouse were erected for demonstration.

The financial analysis has shown the payback period of 3 years for a bamboo polyhouse. As a prototype, this cost is very high. This cost can be reduced in the future based on the optimization for materials, structure, and workforce utilization. The activities done on the field should be standardized and should be done in the workshop to reduce the costs involved.

The major objective of getting the data for vegetable harvest from the polyhouse to show its productivity is not available due to time constraints. The recent picture showing the current status of cultivation is shown in figure 11.2. We have used the secondary data to do a financial analysis.

13.2 Future scope

In the current project, we have developed a bamboo-polyhouse as a protected cultivation method. There is scope to develop and test the performance of the shade-net type of protected cultivation. Through this project, we have solved the problem of year-round production security using Bamboo-Polyhouse. A similar sustainable bamboo-structure can be developed for poultry. The use of bamboo as an industrial shade is proven through many research studies. A similar design can be modified for developing poultry. This will help in reducing the cost and helping the rural household to have the small MSME. The circular aerodynamic model can be developed for the integrated purpose of – shade for cattle, Nutri-Garden, Poultry, etc.

Latest innovations in soil-less cultivation can be adopted under the Bamboo-polyhouse in the region of Jawhar, where the water holding capacity of soil is very low. As BAIF is providing farm ponds to the farmers where they are growing, the fishery can be integrated with Bamboo-Polyhouse to make a large scale-Aquaponics model.

In the next phase of the project, we can demonstrate the supply chain of the Nutri-Garden produce with the local Centralized Kitchen, which makes the mid-day-meal food. While working on a bamboo-structures, we can check for their physical and mechanical properties using the universal testing machine in the next phase.

Chapter 14

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Appendix A

The questionnaire used for interviews of the Nutri-Garden Growers

Details of Responder		
Name/ नाव :	Location of Nutri-Garden (Village/ taluka/ district): गाव/ तालुका/ जिल्हा -	
Occupation / व्यवसाय:	Age/ वय -	Gender/ लिंग -

Qualitative Questions	
Which vegetables are growing in your Nutri-Garden आपल्या परसबागेमाधील भाज्या	
Which Fruits are Growing in your Nutri-Garden आपल्या परसबागेमाधील फळे	
Motivation towards Nutri-Garden / न्यूट्री-गार्डनच्या दिशेने प्रेरणा	

What Constraints Did you faced in cultivating Nutri-Garden आपल्याला लागवड करताना कोणत्या अडचणी आल्या? Also, Rank the constraints from most important to least important तसेच अडचणी अग्रक्रमानुसार लावा	**1** **2** **3** **4** **5** **6** **7** **8**
Any Supporting Organization (NGO, KVK etc) for advice सल्ला देण्यासाठी कोणतीही सहाय्यक संस्था (एनजीओ, केव्हीके इ.)	
Type of fertilizers used Organic/ Natural/ Chemical वापरलेल्या खतांचा प्रकार सेंद्रिय/नैसर्गिक/केमिकल	
Irrigation Water Source परसबागेमधे सिंचनासाठी वापरलेले पाण्याचे स्त्रोत	

Quantitative Questions (please write with units)	
Area of Nutri-Garden परसबाग क्षेत्रफळ -	
Year of starting Nutri-Garden (परसबाग प्रारंभ वर्ष)-	
Initial Investment cost (परसबागेमधे प्रारंभिक गुंतवणूकीचा खर्च)-	
Monthly operating cost परसबागेमधे मासिक खर्च -	
Outputs from Nutri-Garden Kg/day, किलो / दिवस उत्पादन	

Monthly earnings from Nutri-Garden परसबागेमधून मासिक कमाई	

Select the options (one or more) that are applicable/ लागू असलेले पर्याय निवडा (एक किंवा अधिक)			
1.	What type of nutri-garden you are having/ आपल्याकडे कोणत्या प्रकारचे परसबाग आहे	4.	Please select the mediums of nutrition sources you are having कृपया आपल्याकडे येत असलेल्या पोषण स्त्रोतांचे सर्व माध्यम निवडा
	1. Open field/ खुले		*1. Vegetables, fruits भाज्या आणि फळे*
	2. Poly House / shed net house (हरितगृह)		*2. कुक्कुट पालन/ Poultry Farming*
	Motivation Behind Poly house/ nethouse =		*3. Goat farming शेळी पालन*
2.	Outgo of produce from your Nutri-Garden? (आपल्या न्यूट्री-गार्डन मधून उत्पादनाचा आढावा?)		*4. गाय किंवा म्हशी Cow or Buffalo*

	1.	*For Individual Household consumption वैयक्तिक घरगुती वापरासाठी*	5.	Which season Gives More output from Nutri-garden, कोणत्या हंगामात न्यूट्री-गार्डनमधून अधिक उत्पादन मिळते?	
	2.	*Consumption Self-consumption plus selling स्वतः साठी वापर आणि विक्री*		*1.*	*Summer (March – June) उन्हाळा (मार्च - जून)*
	3.	*Selling surplus with value addition मूल्य वाढ प्राक्रियेनंतर अतिरिक्त उत्पादन विक्री*		*2.*	*Winter (Nov- Feb) हिवाळा (नोव्हेंबर- फेब्रुवारी)*
3.	Where do you sell the surplus produce? आपण अतिरिक्त उत्पादन कोठे विक्री करता?			*3.*	*Autumn (July-Oct) शरद (तूतील (जुलै-ऑक्टोबर)*
	1.	*APMC*		*4.*	*Spring (Jan-Feb) वसंत (जानेवारी-फेब्रुवारी)*
	2.	*Village level गाव पातळीवर*	6.	Shape of Nutri-Garden न्यूट्री-गार्डनचा आकार	
	3.	*Market place out of Village (गावाबाहेर बाजारपेठेत)*		*1.*	*Rectangular (आयताकृती)*
	4.	*Organic food market ऑर्गेनिक बाजारपेठेत*		*2.*	*Circular (वर्तुळ)*

Appendix B

Techniques to prepare Organic manure

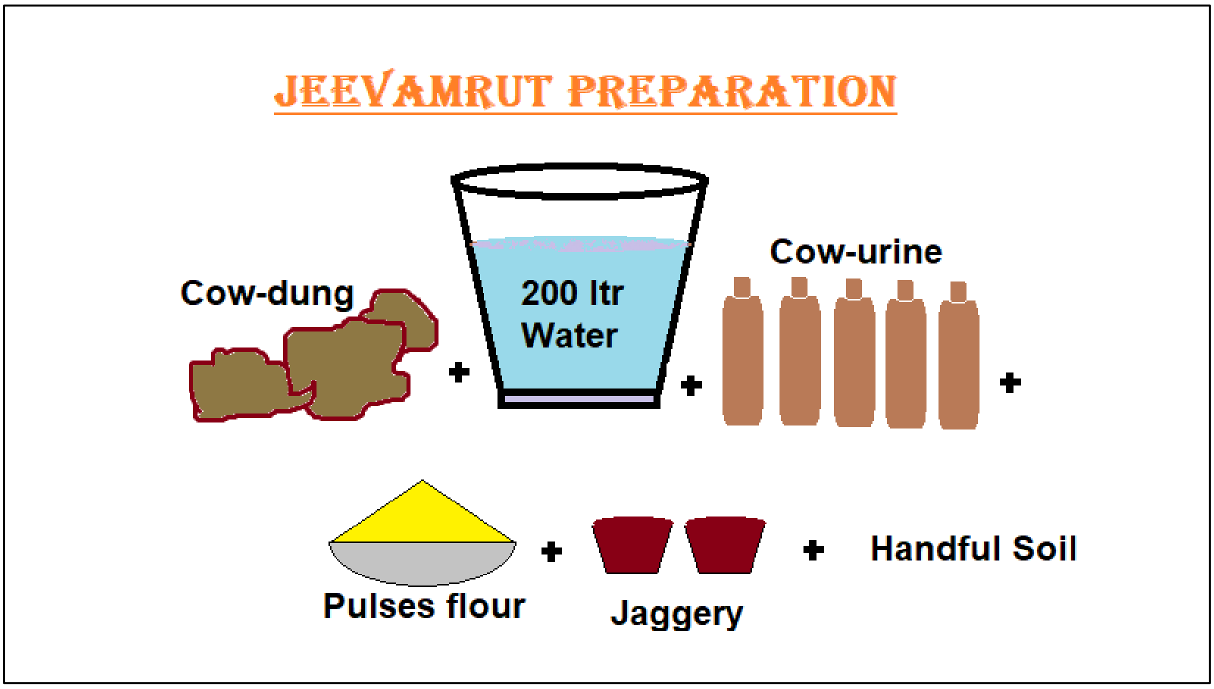

Image a: 1: Preparation of the Jivamrut (Pan India workshop on natural farming, 2020)

Image a: 2: Preparation of Panchgavya (Pan India workshop on natural farming, 2020

Appendix C

Creating a Webpage to Document Nutri-Garden Interventions Done by Different Organisations in India

For the documentation of the intervention studies done by the different organizations in Nutri-Garden the website is underdevelopment. Compendium of the intervention studies are getting received from various organizations –

Link - https://sites.google.com/view/nutri-garden/home

Following figure shows the website for the collecting work and making available the Nutri-Garden intervention work

Image a: 3: Website for Nutri-Garden intervention related documentations in India

Appendix D

Government Directives towards Nutri-Garden

This section covers different directives taken by state and central government to promote the Nutrition Gardens. The following table indicates the various directives taken by state and central government, its short description, and timeline.

Table 1: Directives towards Nutri-Gardens by the State and the Central government in India

Sr. No.	Initiative	Description	Source
Directives by Central Government			
1	School Nutrition Gardens guidelines dated **15th Oct'19**	Includes Objectives of the School Nutrition-Gardens, methods for setting up Nutri-Garden, guidelines on growing the vegetables, etc. School students to engage and participate meaningfully in the activities to inculcate the habit of growing their own vegetables and fruits in the schools and in their homes	*MHRD (Dept. of school, education & literacy), 2019.*
2	Scaling up of Nutri-gardens under Innovation component (Ministry of WCD Circular dated **18th Jun' 20)**	It has been decided to encourage the setting up of Nutri-gardens in Anganwadi. States/Uts may take up as part of the innovation activity	*WCD (Dept. of women and child development), 2020*
3	MORD Circular on – *Guidelines for promoting Nutri-garden for individual beneficiaries and community in convergence with state schemes and NRLM* Dated – **4th May 2020**	This convergence circular describes the • Possible ways to provide Nutri-Garden • Role of MGNREGA in activities to make Nutri-Garden • And restrictions on the activities and support which will not be covered through MGNREGA • Beneficiaries – Beneficiaries of ICDS	*MoRD (Ministry of Rural Development), 2020*

		Priority to Government-Run schools, residential schools, and Anganwadis	
Directives by State Government			
1.	**Govt. of Odisha**, Panchayati Raj & D.W Department **14th May 2020**	Nutri- garden to be developed in 750 GPs of 107 blocks in the convergence of MGNREGS with Odisha Livelihood Mission covering 2.5 lakh individual HHs (SC/ST households, Rural Housing beneficiaries, BPL households, FRA beneficiaries, Small & Marginal farmers, etc.)	
2.	**Govt. of Maharashtra** MoU between Maharashtra DWCD (Rajmata Jijau Mother-Child Health Nutrition Mission (RJMCHNM)) and Reliance Foundation Dated – **23rd Nov' 15.**	Govt. of Maharashtra (DWCD and Rajmata Jijau Mother-Child Health Nutrition Mission (RJMCHNM)) and Reliance Foundation collaborate to minimize malnutrition in children through the adoption of Reliance Nutrition gardens. Reliance Nutrition Gardens (RNGs) were established and promoted in 8 districts of Maharashtra, catering to more than 1 lakh children through 7300 nutrition gardens set up in Anganwadi. The encouraging result of RNGs motivated the Govt. of Maharashtra to expand the program in 8 new districts.	1. *MoU between Maharashtra DWCD and Reliance foundation, 2015* 2. Impact analysis of Nutri-Garden - *Shobha Suri, 2020*
3.	**Govt. of Rajasthan**	To increase the community participation in Anganwadi Services under the Umbrella ICDS scheme, the Government of Rajasthan initiated Nanda Ghar Yojana to bring innovation and create model AWCs (NIPCCD report 2018) The donors/CSR personnel/NGOs/Trustees shall provide all assistance in respect of conducting activities at AWCs along with the support provided by the DWCD, GoR to convert	Internet source

		the AWCs as model AWCs. Support may be provided in regard to repair of AWCs, Kitchen, construction of toilets, **kitchen garden,** and boundary wall.	
4.	**Govt. of Chhattisgarh**	The Chhattisgarh government has set a target to develop 'nutrition gardens' in around 20,000 high schools in the current financial year (Newsletter dated Nov 2019) The concept of "nutrition garden," developed by the Krishi Vigyan Kendra (KVK), was highly appreciated by the Centre, which has recommended other states to follow the model. Nutrition gardens have been developed in around 10,000 out of total of 44,500 high schools in Chhattisgarh in the last one and half years-additional director in the directorate of public instruction (DPI), Chhattisgarh, Maheswar Nayak.	Website of Govt. of Chattisgarh
	Govt. of Kerala	Kudumbashree implements Attappady Special Project in the Attappady block of Palakkad district, Kerala, to uplift the social and economic status of tribal communities of Attappady through Nutrition garden mobile unit (Official web portal of Kerala Local Govt, Govt of Kerala) It was the pilot project of NRLM, Ministry Of Rural Development, Government of India, which envisaged the formation of exclusive institutions of tribal people for bringing in sustainable development in Attappady.	Online Newsletter
	Govt. of Andhra Pradesh	In 2016, the State government had launched a program to grow vegetables in Nutri gardens, with the Sarva Siksha Abhiyan (SSA) as its	Online News letter

		coordinating agency, for school kids in the district. Currently, 527 schools come under the purview of the program that benefits around 4.50 lakh students (Newsletter dated Nov 2018) Sixteen types of vegetables, leafy and non-leafy, are being grown in the open lands. The horticulture department is engaged in training teachers and students in farming in these ‘Nutri-gardens.’ ICDS staff and Kotapalli Mandal are supervising the works. Vegetables grown are also supplied to local Anganwadi centers	

Appendix E

Formed Filled by Farmers During Focused Group Discussion

The following is a two-pager form filled by the farmers during the focused group discussion at Annamrita Centralized kitchen, Wada, Palghar.

Survey of Farmers to be selected for subsidised Bamboo-Polyhouse
IIT Bombay-BAIF Project
आई. आई. टी. बॉम्बे- बायफ प्रोजेक्ट

Name नाव – Address पत्ता – Mobile No. मोबाईल नंबर : Distance of farm from Annamrita Kitchen (Kanchad phata, Wada-Manor road) अन्नामृता किचन (कांचन फाटा, वाडा-मनोर रोड) पासून शेताचे अंतर	Education शिक्षण – Age वय – Land Holding - जमीनिची उपलब्धता
Motivation to join Polyhouse Project पॉलिहाऊस प्रकल्पात सामील होण्याची प्रेरणा/कारण -	
Willingness to contribute towards 20% (upto Rs. 10,000) of the project / प्रकल्पाच्या 20% (10,000 रुपये) पर्यंत योगदान देण्याची इच्छा Yes होय ☐ No नाही ☐	Polyhouse construction / completion (15^{th} – 20^{th} Dec. 2020) पॉलीहाऊस बांधकाम / पूर्ण (15^{th} – 20^{th} Dec. 2020)
Name of Family members who will assist in growing Vegetables in Polyhouse / पॉलीहाऊसमध्ये भाजीपाला वाढण्यास मदत करणारे कुटुंब सदस्याचे नाव -	
Any prior experience in cultivation of Vegetables भाजीपाला लागवडीचा कोणताही पूर्वीचा अनुभव	Any other crops (other than vegetable) is growing currently इतर कोणते पीक (सध्या इतर कोणते पीक उत्पन्न करत आहात)

<table>
<tr><td rowspan="5">Water source
पाण्याचा स्रोत -</td><td colspan="4">Seasonal Availability of water (Tick √)
पाण्याची हंगामी उपलब्धता = (√ करणे)</td></tr>
<tr><td></td><td>Year round
वर्षभर</td><td>Nov. to Jan.
नोव्हेंबर–जानेवारी पर्यंत</td><td>Feb. to May
फेब्रुवारी-मे पर्यंत</td></tr>
<tr><td>Very little
अति कमी</td><td></td><td></td><td></td></tr>
<tr><td>Little
कमी</td><td></td><td></td><td></td></tr>
<tr><td>Satisfactory
समाधानकारक</td><td></td><td></td><td></td></tr>
<tr><td>Any previous experience in marketing the vegetables / fruits
भाज्या / फळे विकण्याचा पूर्वीचा अनुभव</td><td colspan="4">Any other relevant information इतर कोणतीही संबंधित माहिती
-</td></tr>
<tr><td colspan="5">* Willingness to bear additional cost required to run polyhouse (seeds, labour etc.)
पॉलीहाऊस चालवण्यासाठी वरील खर्च (बियाणे, मजुरी इ.) देण्यासाठी तयार आहात का
Yes तयारी आहे ☐ No नाही ☐</td></tr>
<tr><td colspan="5">* Note : During the one year 3 cycles of vegetable cultivation and sales expected from selected farmers. Data on above (production, quantity, expenditure, revenue) will be collected by IITB-BAIF team.
* नोट : एका वर्षातील तिन्ही सायकल मधील भाज्यांचे उपाध्या (खर्च व कमाई) ही माहीती निवडलेल्या शेतकर्याकडून प्रोजेक्ट घेईल</td></tr>
<tr><td colspan="5">Is the chosen Farmer ready to sign Undertaking / निवडलेला शेतकरी हमीपत्रावर सही करण्यास तयार आहे का?
Yes होय ☐ No नाही ☐</td></tr>
<tr><td colspan="5">(Name and Signature) (नाव व सही)</td></tr>
</table>

Appendix F

Quantitative Data Analysis for Dietary Pattern of Different Food Groups in Jawhar Block

The questionnaire used to collect the consumption data –

Table F. 1: Sheet used for collecting the dietary data for households with Nutri-Gardens

Food Group	**Season -->**	July-Oct (Rainy)		Nov-Feb (Winter)		March-June (Summer)	
	Source of food -->	Externally purchased	Self Grown	Externally purchased	Self Grown	Externally purchased	Self Grown
Staple/Cereal-Rice (kg)	Rice						
Tubers (vegetables that grow underground)	Potato						
	Radish						
	Carrot						
	Alukand						
	Karande						
	Suran						
Vegetables	Brinjal						
	Bhindi (Okra)						
	Gavar (Cluster Beans)						
	Methi (Fenugreek)						
	Onion						
	Wal						
	Karali (Bitter Gourd)						
	Gourd						
	Ambadi						
	Drumsticks						
	Flower						
Fruits	Mango						
	Guava						
	Banana						
	Cashew						
Meat	Mutton						
	Chicken						
	Eggs						
Fish	Prawns						
	Local variety						

	Bagada						
	Surnai						
	Dried Fish						
Milk							
Spices, condiments, beverages	Garam masala						
	Haldi						
	Black pepper						
	Salt						
	Tea						
	Coffee						
	Pickle						
Pulses	Tur						
	Udid						
	Mung						
	Harbhara						
	Masur						

The above table is used to collect the consumption data during interviews. The data was collected based on memory-based responses, and then it was modified to kg/month consumption.

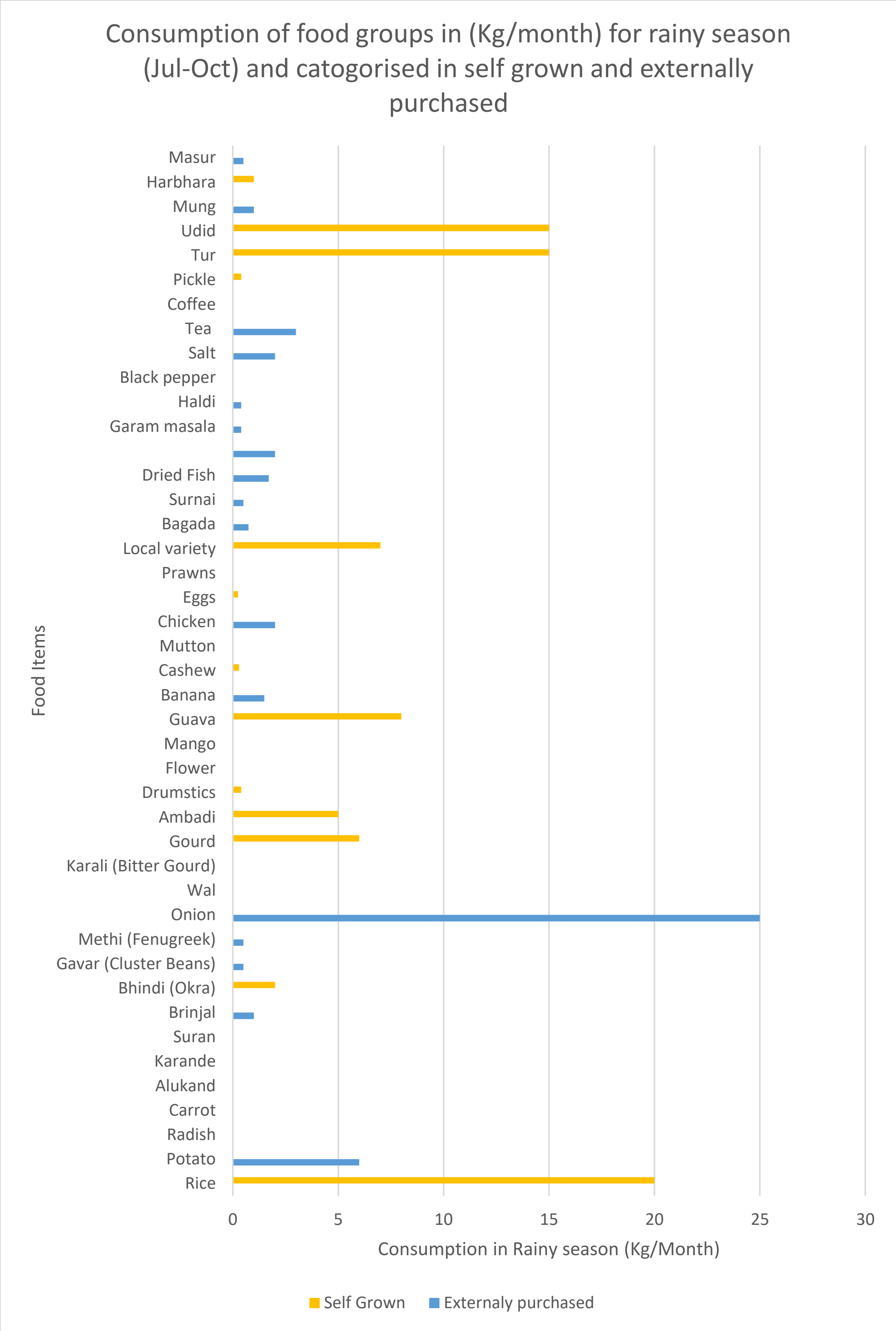

Image F. 1: Consumption of food groups in (Kg/month) for rainy season (Jul-Oct) and categorised in self-grown and externally purchased

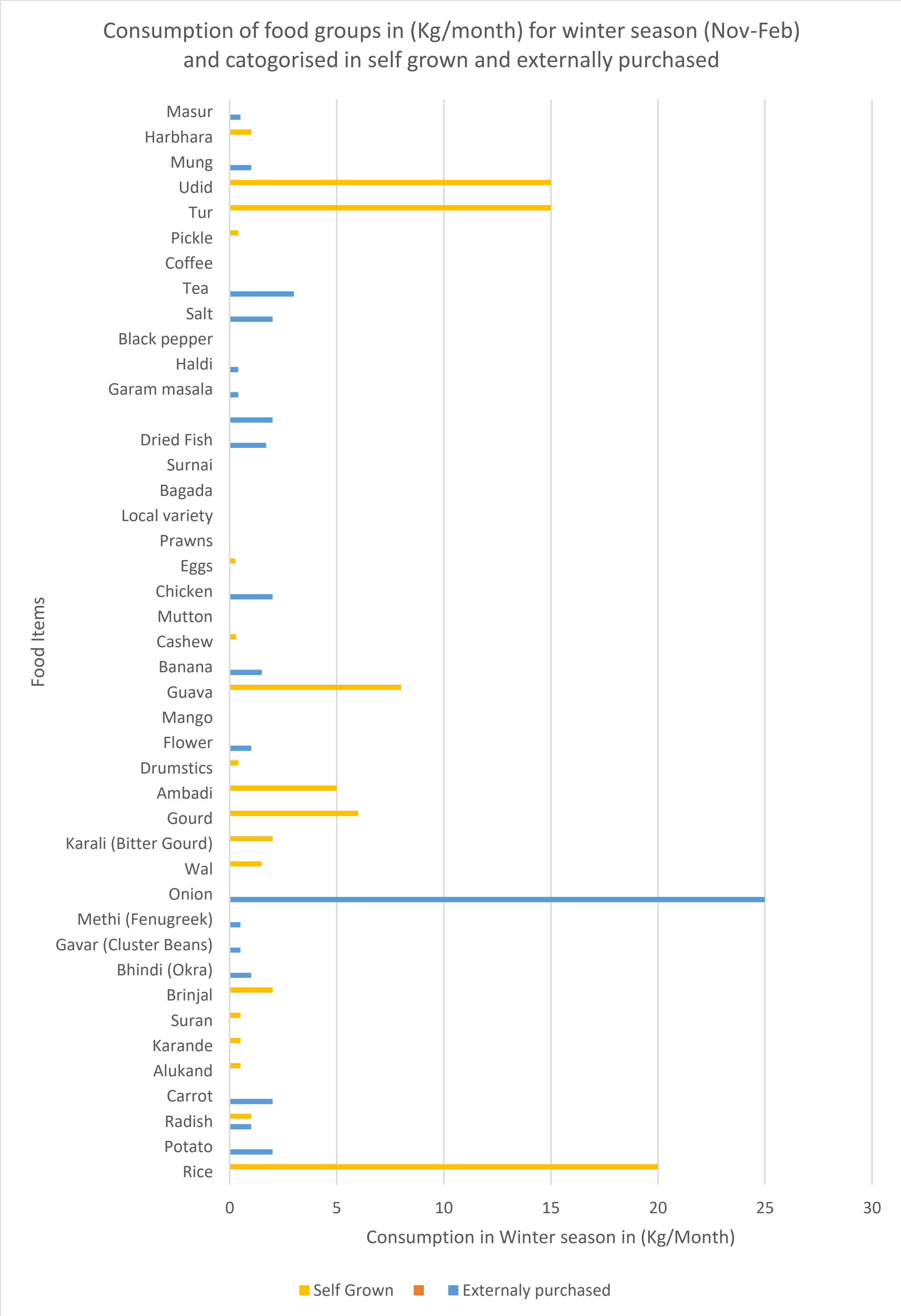

Image F. 2: Consumption of food groups in (Kg/month) for the winter season (Nov-Feb) and categorized in self-grown and externally purchased

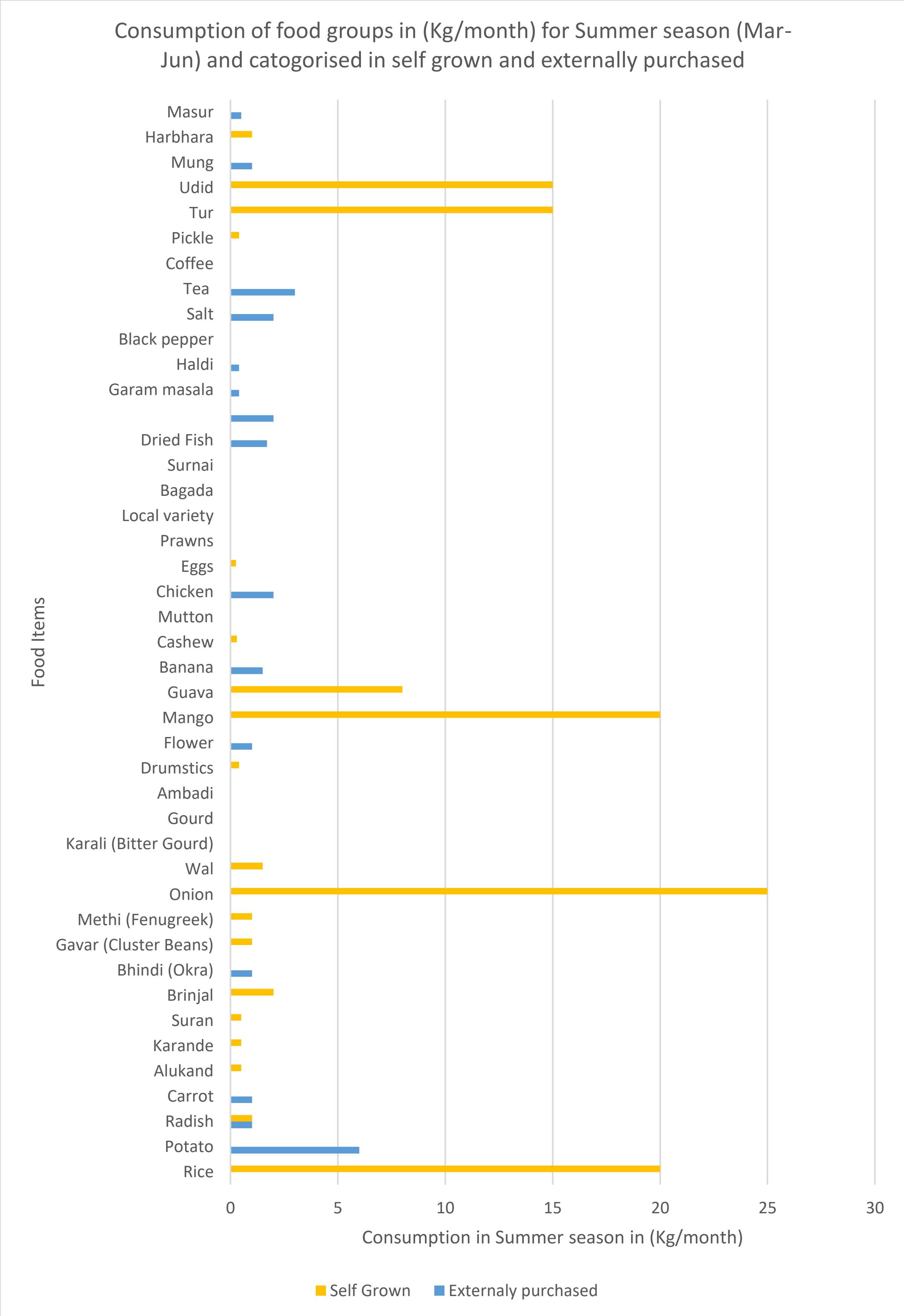

Image F. 3: Consumption of food groups in (Kg/month) for Summer Season (Mar-Jun) and categorized in self-grown and externally purchased