Development of Climate Resilient Year Round Home Garden Model for Improving Food and Nutritional Security of Resource-Poor Households in Eastern India
(Homegarden Model for Resource-Poor Households)

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Abstract. Improving food security as well as reducing poverty and hunger is the most important challenges the world is facing during COVID-19 period. Indians are facing the same particularly, in eastern part where poverty and malnutrition is a big problem. Climate change has impacted productivity of crops and sustainability of ecosystem. This study was done with the objective to develop climate resilient home garden model for year round production of nutritional vegetables. A model of 100 m^2 area was developed and established at ICAR-RCER, Patna during 2019–21. The year round vegetable patterns were divided into three cropping seasons per year including winter (mid-October to mid-March), pre-rainy (mid-March to mid-June) and rainy (mid-June to mid-October). The season-wise production was highest in winter (166.6 kg) followed by monsoon (91.9 kg). The results suggest that a homegarden may give a considerable amount of the recommended dietary allowance (RDA) of iron (60.70%), calcium (52.29%), 7415 g/day (>100%) vitamin A, and 89.91 mg (>100%) vitamin C per day to each family member.

Keywords: Home garden · Nutritional security · 100 m^2 Model · Vitamin A · Vitamin C

1 Introduction

India is a developing country inhabiting 139.6 billion people with a total geographical area of 3,287,590 km^2 [1]. It accounts for over 50% employment in the country. However, approximately one-third of the world's children under the age of five are malnourished; one in every two women of reproductive age is anaemic, one in every three infants under

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the age of five is stunted, and one in every five children under the age of five is wasted [2]. Stunting is 10.1% higher in rural areas than in urban areas, indicating inequalities [3]. Several projects have been established over the years to enhance the population's nutrition and health status; yet, micronutrient insufficiency still affects a considerable section of the population. Nutritional anaemia due to deficiencies of micronutrients such as iron, folic acid and vitamin B_{12} affects almost 50–60% preschool children and women, while vitamin A deficiency, iodine-deficiency disorders (IDD) and zinc deficiency are other major nutritional deficiencies in Indian population [4]. These micronutrient insufficiencies can cause a variety of diseases, impede physical growth, retard child growth, lengthen and worsen illness, impair work performance, and slow social and cognitive development [5]. Vegetables are characterized as the food with the highest micro-nutrient density by low energy content, containing large amounts of vitamins and minerals. Due to their composition, vegetables have potential to prevent and alleviate micronutrient deficiencies, also commonly referred to as 'hidden hunger' [6].

Climate change has hampered agricultural productivity, causing prices to rise, limiting food access for the poor and middle classes. Vegetable productivity effects vary, making nutrient-dense meals like nuts, fruits, and vegetables more expensive. As a result, customers are more likely to rely on less expensive alternatives such as starchy staples or highly processed foods, which may be nutritionally inferior. Indigenous vegetables, on the other hand, are often more nutrient dense than global vegetables [7], require less external inputs, and can withstand abiotic and biotic challenges when cultivated on a local scale in mixed cropping systems, as is the case in their origin areas. Due to the loss of biodiversity and accompanying indigenous knowledge, the value of these indigenous vegetables in food security initiatives is diminishing. Climate vagaries are root cause of loss of indigenous vegetables. Major causes, effect and social impacts of climate changes are explained diagrammatically in Fig. 1.

Climate change is a cause of human actions viz. Rapid industrialization, non-renewable energy use, deforestation, agricultural practices, livestock methane emission, pollution and the like more. The effect of these is now prominently visible. Raising

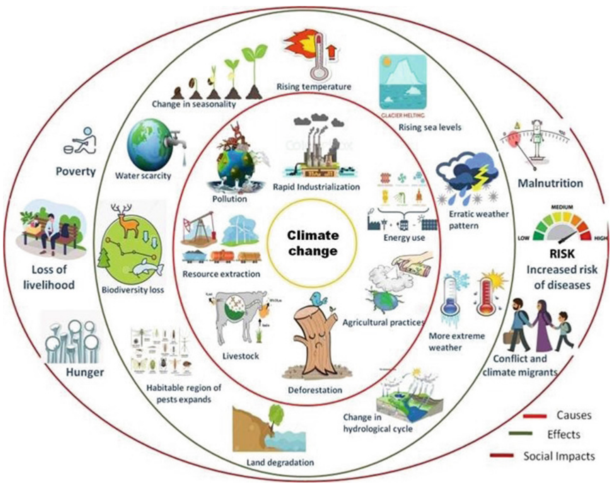

Fig. 1. Causes, effect and social impacts of climate change.

temperature, sea level, erratic weather pattern, more extreme weather, changes in hydrological cycles, seasonality change, land degradation, habitable region of pests expands, biodiversity loss, water scarcity etc. are felt day by day. These changes in another way are impacting society by increasing poverty, loss of livelihood, hunger, increasing risk of diseases, malnutrition, migration and so on (Fig. 1).

Due to poor transportation, limited facilities, and low income, the majority of the young male population in rural areas migrates seasonally to urban areas to support their families financially [8]. In the family, only women, children and the elderly stay in rural areas. Therefore, homegarden is direct and affordable way to consume vegetables and best option to provide better health and overcome malnutrition. All the activities like establishing and maintain the homegarden are performed by family members (women, children and the elder people). It not only supplies fresh vegetables but also saves some money as vegetables are now quite costly in the market. The fresh vegetables obtained from their own garden, not only ensures better nutritious diet but there is also a delicate psychology behind the taste. In addition, the home garden's functions and product complement field agriculture. While field crops provide the majority of the household's energy, the homegarden provides nutritious vitamin and mineral-rich vegetables to balance the diet. To sustain bad situations such as crop failure, energy-rich vegetable staples such as sweet potato and cassava, as well as herbs and spices, are planted. The study's aim was to use homestead resources in scientific methods to produce fresh vegetables throughout time and space, as well as to improve the family's nutritional supply throughout the year.

2 Material and Methods

During the 2019–2020 and 2020–21 cropping seasons, the research was conducted at the ICAR Research Complex for Eastern Region's research farm (25 35' N, 85 05' E, and 51 m above mean sea level) in Patna, Bihar, India. With an average annual rainfall of 1167 mm (70–75% of which falls between July and September), a minimum temperature of 7.4–10.4 °C in January, and a maximum temperature of 35.1–39.6 °C in May, the climate of the region is subtropical hot and humid. The region's annual mean humidity was 67.2%, with the highest (80.5%) and lowest (50.0%) percentages occurring in September and April, respectively. In the 0–15 cm surface layer, the soil had a silty loam (Vertic Endoaqualfs) texture with a pH of 7.22 and an electrical conductivity of 0.17 dS m-1. A vegetable based homegarden model of 100 m^2 was established at ICAR-RCER, Patna. A total of 24 conventional and non-traditional vegetables were chosen for year-round vegetable growing in this model and were planted in modest (3 m 2 m) beds. Year-round vegetable patterns were separated into three cropping seasons: winter (mid-October to mid-March), pre-monsoon summer (mid-March to mid-June), and rainy season (mid-June to mid-August) (mid-June to mid-October). Some vegetables in each model were only cultivated for one season, such as radish, pea, coriander, broccoli, cauliflower, and cabbage, while others were grown for two seasons, such as yard long bean, okra, sponge gourd, ridge gourd, and bottle gourd), while still others were grown all year (Table 1). To boost climate adaptability, local traditional vegetables were also included in this model.

Table 1. List of homestead garden plant species with local name, english name, scientific name, family and cropping season used in the study

No	Local Name	English Name	Scientific Name	Family	Cropping Season
1	*Tamatar*	Tomato	*Solanum lycopersicum*	Solanaceae	Mid Oct–Mid Mar
2	*Baigan*	Egg plant	*Solanum melongena*	Solanaceae	Mid June-Mid Mar
3	*Mirch*	Chilli	*Capsicum annum*	Solanaceae	Mid June-Mid Mar
4	*Phul gobhi*	Cauliflower	*Brassica oleracea* var *oleraceae*	Cruciferae	Mid Oct–Mid Mar
5	*Patta gobhi*	Cabbage	*Brassica oleracea* var *capitata*	Cruciferae	Mid Oct–Mid Mar
6	*Broccoli*	Broccoli	*Brassica oleracea* var *italica*	Cruciferae	Mid Oct–Mid Mar
7	*Palak*	Palak	*Spinacia oleracea*	Amaranthaceae	Mid Oct–Mid Mar
8	*Dhaniya patta*	Coriander leaves	*Coriandrum sativum*	Apiaceae	Mid Oct–Mid Mar
9	*Sarson saag*	Mustard leaves	*Brassica* sp.	Cruciferae	Mid Oct–Mid Mar
10	*Matar*	Pea	*Pisum sativum* L.	Fabaceae	Mid Oct–Mid Mar
11	*Bhindi*	Okra	*Abelmoschus esculentus*	Malvaceae	Mid Mar–Mid Oct
12	*Bora*	Yard long bean (YLB)	*Vigna unguiculata ssp. unguiculata cv.-gr. Sesquipedalis*	Fabaceae	Mid Mar–Mid Oct
13	*Lauki*	Bottle gourd	*Lagenaria siceraria*	Cucurbitaceae	MidMar–Mid June
14	*Jhinga*	Ridge gourd	*Luffa acutangula*	Cucurbitaceae	Mid Mar–Mid Oct
15	*Nenua*	Sponge gourd	*Luffa cylindrica*	Cucurbitaceae	Mid Mar–Mid Oct

(*continued*)

Table 1. (*continued*)

No	Local Name	English Name	Scientific Name	Family	Cropping Season
16	*Parwal*	Pointed gourd	*Trichosanthes dioca*	Cucurbitaceae	Mid Jun–Mid Oct
17	*Laal saag*	Joseph's coat	*Amaranthus tricolor*	Amaranthaceae	Mid Jun–Mid Oct
18	Kalmi saag	Water spinach	*Ipomoea aquatica*	Convolvulaceae	Mid Jun–Mid Oct
19	Poi saag	Indian spinach	*Basella alba*	Basellaceae	Mid Mar–Mid Oct
20	Gajar	Carrot	*Daucas carota*	Apiaceae	Mid Oct–Mid Mar
21	Mooli	Radish	*Raphanus sativus*	Cruciferae	Mid Oct–Mid Mar
22	Chukunder	Beet Root	*Beta vulgaris*	Amaranthaceae	Mid Oct–Mid Mar
23	*Lafa saag*	Chinese mellow	*Malva verticellata*	Malvaceae	Mid Oct–Mid Mar
24	*Bathua saag*	*Bathua*	*Chenopodium album*	Amaranthaceae	Mid Oct–Mid Mar
25	*Sem phali*	Indian bean	*Dolichos lablab*	Fabaceae	Mid Oct–Mid June
26	*Chiramira saag*	Jute greens	*Crotolaria sp.*	Crotolareaceae	Mid Jun–Mid Oct
27	Papita	Papaya	*Carica papaya*	Caricaceae	Round the year

During the cultivation of each vegetable crop, standard cultivation techniques were used. Irrigation was provided on a need-to-know basis. Unless large infestations were noted, pests and disease were primarily handled mechanically, with no chemical application. Weekly harvest data were collected using a standard weighing machine from a 100 m^2 model, and data were evaluated based on weekly per head per day availability and nutrition calculations using Indian Food Composition tables [9]. Total production was also used to calculate the economic return.

3 Results

Each homestead's productivity and nutritional supplying ability can be improved by using 100 m^2 of land (suitable for family of 4 members).

Table 2. Year round homestead production pattern and yield in 100 m^2 model (in Kg)

S.N	Pattern	*Winter*	*Summer*	*Rainy*	Total
1	Broccoli-YLB-Okra	14 ± 2.7	15.4 ± 3.2	14.5 ± 1.8	43.9 ± 7.7
2	Carrot-Bottle gourd-Water spinach	12.9 ± 3.6	17.2 ± 5.2	14 ± 2.3	44.1 ± 11.1
3	Palak-YLB-Sponge gourd	12.6 ± 2.5	15.8 ± 1.8	14 ± 1.4	42.4 ± 5.7
4	Sem-Okra-Red Amaranth(for stem)	7 ± 2.4	15.7 ± 1.2	10 ± 2.4	32.7 ± 6
5	Cauliflower-YLB-Basella	15.2 ± 3.4	14.8 ± 2.1	8 ± 2.3	38 ± 7.8
6	Pea- Red Amaranth -YLB	12.3 ± .1.9	12 ± 1.8	17 ± 3.8	41.3 ± 7.5
7	Spinach-Onion-YLB	10.3 ± 2.3	13.1 ± 3.1	14.2 ± 1.2	37.5 ± 6.6
8	Radish-Bottle gourd- Red Amaranth	12 ± 4.2	16.2 ± 2.3	10 ± 1.6	38.2 ± 8.1

Note: YLB-Yard long bean.

3.1 Year Round Nutri-Garden Vegetable Pattern and Production

A total of 24 vegetables were chosen for year-round vegetable growing in a 100 m^2 model. Vegetable patterns were separated into three cropping seasons per year: winter (mid-October to mid-March), pre-rainy (mid-March to mid-June), and rainy (mid-June to mid-September) (mid-June to mid-October). Table 2 shows the year-round homestead production pattern utilized in the 100 m^2 model.

Some vegetables in each model were only cultivated for one season, such as radish, pea, coriander, broccoli, cauliflower, and cabbage, while others were grown for two seasons, such as yard long bean, okra, sponge gourd, ridge gourd, and bottle gourd), while others were grown throughout the year. The largest yield occurred in the winter (166.6 kg), followed by the rainy season (91.9 kg). Non-traditional vegetable and papaya are planted along the bund's margins. Pre-rainy season yielded the least amount of vegetables. This is primarily owing to the fact that the pre-rainy season lasts from mid-March to mid-June, which is also the driest time of year. Water spinach and basella, two non-traditional green vegetable crops used to make saag (pot herb), have been incorporated in the model and produced in bunds. Comparative study of different cropping pattern their yield potential and nutrition availability of 100 m^2 model.

The year round vegetable patterns were divided into three different seasons per year including winter (mid-October to mid-March), pre rainy (mid-March to mid-June) and rainy (mid-June to mid-October). The highest yield potential was found in cropping pattern carrot-bottle gourd-water spinach (44.1 ± 11.1 kg) followed by broccoli-YLB-Okra (43.9 ± 7.7 kg) and palak-YLB-Sponge gourd (42.4 ± 5.7 kg). However, lowest yield production was observed in Sem-Okra-Red Amaranth (32.7 ± 6 kg) pattern (Table 2).

Nutrition-wise, highest energy (23892 kcal), protein (1849.9 g) and fat (143.2 g) were found in Pea-Red Amaranth-YLB cropping pattern. It was calculated based on the food composition table of NIN [9]. However, highest Vitamin A (1876380 IU) and Vitamin C (20888 mg) was found in Carrot-Bottle gourd-Water spinach and Cauliflower-YLB-Poi cropping pattern respectively. It was interesting to notice that cropping pattern Pea- Red

Amaranth -YLB was reported highest in thiamine (58.55 mg), riboflavin (68.52 mg) and niacin (653.7 mg). Similar pattern was also observed in minerals content Pea- Red Amaranth -YLB cropping pattern reported highest content of calcium (63078 mg), iron (34258 mg) and phosphorous (1180.7 mg). Therefore, from this cropping pattern study from nutrition point of view, for vitamin A deficiency problem Carrot-Bottle gourd-Water spinach is best option to adopt as carrot and water spinach are highly rich in Vitamin A, and bottle gourd is rich in other minerals and fiber. For Vitamin C, Cauliflower-YLB-Poi cropping pattern was found best. Vitamin C rich vegetables are help in boosting immunity and heal easily from any cut or skin disease, so this vegetable combination is highly suitable for household having small children. Eastern Indian people are suffering from anaemia than other parts of country, so Pea- Red Amaranth–YLB cropping pattern are highly suitable for this area. This pattern can provide a significant portion of major minerals and vitamins.

3.2 Effectiveness of the Homegarden in Fulfilling Nutritional Security

The weekly harvest data were recorded from 100 m^2 model through standard weighing machine. Data were analyzed based on weekly per head per day availability (Table 3).

Table 3. Nutritional availability from different vegetable pattern from 100 m^2 model

S.N.	Plot Wise Crop Sequence	Energy (kcal)			Vitamins					Minerals		
		Energy (kcal)	Protein (g)	Fat (g)	A ('000 IU)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Ascobic acid(mg)	Ca (mg)	P (mg)	Fe (mg)
1	Broccoli-YLB-Okra	16947	1318.5	101.8	513.4	34.93	60.56	351.6	19861	35078	28126	756.5
2	Carrot-BG-WS	11402	582.3	116.2	**1876.4**	19.9	26.37	195.8	6212	23613	12804	448.7
3	Palak-YLB-Sponge gourd	13380	1124.2	97.4	1230.9	26.46	47.82	273.8	8638	28134	18408	939.6
4	Sem-Okra-RA (S)	13355	964.3	130.4	945.9	20.99	49.9	263.2	12571	64762	21852	864.5
5	Cauliflower-YLB-Poi	13768	1152.4	92	1136.2	29.48	41.32	279.6	**20888**	30456	20044	633.2
6	Pea-RA-YLB	**23892**	**1849.9**	**143.2**	1338.3	**58.55**	**68.52**	**653.7**	17581	**63078**	**34258**	**1180.7**
7	Spinach-Onion-YLB	15820	966	71	947.2	30.2	33.9	238	8490	25490	19860	751
8	Mustard saag-BG-RA	8484	516.4	94.4	910.9	15.06	34.02	212.4	11700	47140	12560	391.4

YLB-Yard long bean, WS-Water spinach, BG-Bottle gourd, RA- Red Amaranth, S-Stem.

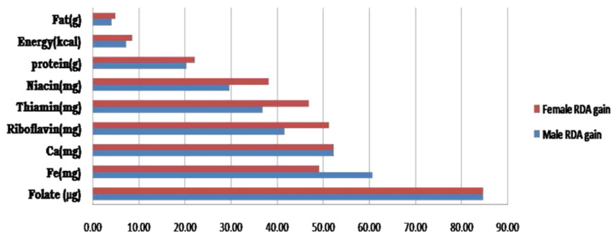

Fig. 2. Comparison between requirement of different nutrient as per RDA of ICMR of male and female and availability through studied homegarden.

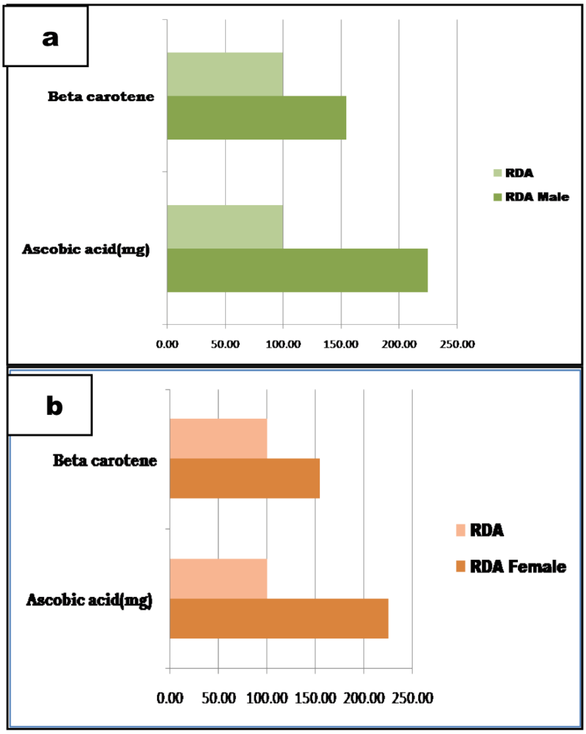

Fig. 3. Comparison between requirement of beta carotene and ascorbic acid as per RDA of ICMR of male (3a) and female (3b) and availability through studied home garden.

The National Institute of Nutrition's 2017 Indian Food Composition Tables were used to compute the nutrition. The results show that a home garden can provide a significant portion of a male's RDA for protein (20.27%), energy (7.23%), and essential fat (4.03%), as well as micronutrients like iron (60.70%), calcium (52.29%), and essential vitamins like riboflavin (41.62%), thiamin (36.85%), niacin (29.65%), and folate (29.65%) (84.74%). Similarly, for female, protein (22.11%), energy (8.49%), essential fat (4.84%), micronutrients like iron (49.14%), calcium (52.29%) and essential vitamin like riboflavin (51.23%), thiamin (46.90%), niacin (38.12%) and folate (84.74%). A graphical representation is shown in Fig. 2. Additionally home garden provides 7415 µg/day vitamin A, and 89.91 mg vitamin C per day to each head in the family. This showed that availability of vitamin A and vitamin C is at par or higher than the recommended dietary allowance (RDA) of male and female (Fig. 3a, b).

It was also observed that performance and yield potential of leafy vegetables was better and major provider of iron, calcium, vitamin A and folic acid. Legume vegetables are major provider of protein, iron and zinc. Two traditional leafy vegetable crops viz., kangkong, and basella meant for saag preparation in pre-rainy months and lafa saag in winter month was included in the model. Perennial vegetables (papaya and curry leaf) included in this model buffering the household against vegetable shortages.

Table 4. Input cost for preparing home garden

SN	Inputs (Rs)	Cost (R)
1	Seed (Rs)	430.00 ± 60.00
2	Bio-pesticide (Rs)	820.00 ± 95.00
3	Others (Rope, GI wire, Bamboo sticks)	670.00 ± 50.00
	Total cost	1920.00 ± 48.00

1$ = 74.5 Rupee.

3.3 Economic Viability of Homegarden

The economic return was also calculated on the basis of total production. Total vegetable produced from 100 m^2 was 245.5 kg/year. Cost of seed and other input (chemicals, rope, bamboo sticks, GI wire) was Rs.1920/-. This study excludes labour cost to maintain a garden as this type of kitchen garden maintain by women or elder people of the respective household.

Taking Rs.20 as average price of vegetables the total output from 100 m^2 is Rs. 4910/year. The benefit cost ratio is 2.57:1 from 100 m^2 models. Homegarden model would be an effective approach to improve nutritional security while also providing an additional source of income, since the family would be able to sell a portion of the garden's output, reaching household self-sufficiency (Table 4).

4 Discussion

In rural parts of developing countries, homegrown vegetables are important for providing food and nutritional security [10, 11]. According to the Indian Council of Medical Research (ICMR), an adult man or woman needs at least 300 g of vegetables per day, however people in eastern India consume less than 230 g/head/day [12]. According to the findings, the problem of malnutrition is exacerbated by rural people's lack of nutritional understanding, resulting in a lower intake of balanced foods, particularly green vegetables [13]. As a result, a scientific home garden model is needed to supply year-round fresh and healthy vegetables and fruits as well as economic benefit to the ultra-poor farmers of eastern India. The scientific approach for home gardens would aid in increasing vegetable and fruit consumption, hence enhancing farmers' livelihoods through improved nutrition [14, 15]. It also aids in the reduction of malnutrition, particularly among children and women, as well as the treatment of the majority of rural eastern Indians' nutritional problems. Vegetables and fruits are the only source of important vitamins (A and C), and deficiency in these vitamins causes poor vision and immunity. To solve these difficulties, the 100 m2 model was created, which is based on family size and provides year-round vegetable production.

Small mixed vegetable gardens can provide a significant portion of the recommended daily requirement for protein (10%–20%), iron (20%), calcium (20%), vitamin A (80%) and vitamin C (100%) [16]. Similar results were found in this study also. These models can provide a significant percentage of the recommended dietary allowance (RDA) of iron (60.70%), calcium (52.29%) and essential vitamin like Vitamin A and C (100%), riboflavin (41.62%), thiamin (36.85%), niacin (29.65%) and folate (84.74%). Traditional (indigenous) vegetables are nutrition-dense and well adapted to climate change [17]. Therefore, to increase the availability of iron and other micronutrient, we included climate resilient nutritious vegetables like Chinese mellow, chenopodium, basella and water spinach in home garden model. Availability of micronutrient was also studied in different cropping pattern. It was noted that Pea-Red Amaranth-YLB cropping pattern yielded highest amount of iron, calcium and other micronutrient. For the pregnant and lactating woman this cropping system can play important role. Red amaranth is a good source of calcium (397 mg per 100 g), Pea is a good source of phosphorus (116 mg per 100 g) and iron (3.9 mg per 100 g) and YLB is a good source of fiber. In this cropping pattern, Pea and yard long bean are rich in minerals and Red Amaranth is also rich in Vitamin A. Legume vegetables rich cropping pattern increases availability of micronutrient.

Following this model, a poor household can meet their daily vegetable demand throughout most months of the year, implying improved nutritional security and reduced malnutrition in rural eastern India.

A homestead garden can contribute to a considerable portion to household's income. In Indonesia a home stead garden was estimated to contribute 7–56% of the households' income [18]. In Bangladesh by selling the fruits and vegetables it was reported that the households earns an average US$4 per month [19], the figure can goes up to US$300 in five month period as reported from Lima slums [20]. In our case, Rs. 4910 (US$ 65)/year from 100 m^2 was estimated as total output which can be saved by the households adopted this model.

5 Conclusion

In conclusion, our 100 m^2 models of home garden appeared to be climate resilient as the local cultivars and suitable varieties were selected for the model based on the agro-ecological parameters. Farmers were able to meet their daily vegetable need in most months of the year after adopting this model, indicating an increase in food security and reduction in malnutrition in rural eastern India. It was calculated a family can produce vegetables 630–650 kg vegetables worth Rs 12618 every year by investing Rs 4910 with a benefit cost ratio of 2.57: 1. A poor family having 100 m^2 area in backyard can adopt this model, can save a considerable expenditure incurred for the purchase of vegetables, and above all, it can enhance the food and nutritional security of the household.

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