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Climate resilience technology for year round vegetable production in northeastern Bangladesh

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A B S T R A C T

A study was carried out to investigate climate resilience vegetable production prospect using tower gardening technology during the period of July 2017 to December 2017 in low-lying areas of northeastern Bangladesh (Sylhet and Moulvibazar). Total 24 participants of DFID and EU funded Suchana program (January-December'2017) were involved in the study. Two sizes of tower (a) medium size (4.5 feet diameter and 5.0 feet height) (b) small size (3.0 feet diameter and 4.0 feet height) and two types growing media protecting material (i.e. plastic bag & bamboo mat) were used separately to perform the study. To prepare the growing media (50%) soil, (40%) cow dung/compost and (10%) decomposed water hyacinth were used. Mainly two types of vegetables, climbers (i.e. bottle gourd and bitter gourd) and herbaceous (i.e. kangkong, Indian spinach, red amaranth and okra) were planted to conduct the study. The vegetable production was significantly influenced by tower size & growing media protecting materials and the highest vegetable production (84.35 kg tower^{-1} and 42.17 t ha^{-1}) was recorded in medium size tower with plastic bag whose sold value was BDT 1968.50 tower^{-1} and BDT 98.43 Lac ha^{-1}, respectively. In addition, the lowest vegetables production (42.08 kg tower^{-1} and 21.04 t ha^{-1}) was recorded in small tower with bamboo mat that's sold value was BDT 955.92 tower^{-1} and BDT 45.99 Lac ha^{-1}, respectively. Cost-benefit ratio (2.85) was recorded in medium tower and 1.73 in small tower. In disposal pattern of vegetables major portion was used for family consumption (80% and 90%), distribution (15% and 10%) and sold (5% and 0%) in medium and small tower garden, respectively. From the result it may say that both size of tower garden were technically feasible to grow vegetable in inundated situation but medium size tower made of plastic bags performed better than bamboo mat due to less nutrient loss through leaching. The study found tower gardening on medium size tower with plastic bag could be a potential and effective option for year round vegetable production in climate vulnerable communities of Bangladesh.

Keywords: Tower gardening, Vegetable Production, Climate resilience, Disposal pattern, Low-lying area.

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Introduction

Sylhet, the northeastern division of Bangladesh is an extensive rain fat area where the adverse effects of climate change have posed significant impacts on agricultural production (Sunny *et al.*, 2020a; Sunny *et al.*, 2018). In addition, floods caused by heavy rain in June-September adversely affected agricultural sector in Bangladesh (Islam *et al.*, 2018a; Islam *et al.*, 2018b; Sunny *et al.*, 2020b). Resulting, agricultural production especially vegetables production is hindered every year due to frequent rainfall induced flash flood. On the other hand scarcity of irrigation water during winter restricted agricultural production especially vegetables that caused price hike due to limited access of vegetables (Islam *et al.*, 2018c; Sunny *et al.*, 2020c). The soil productivity is also low due to high acidic soil that hampers the vegetable production (Kuddus *et al.*, 2018). According to Salinger *et al.* (2005) a number of technologies and strategies that could help to reduce the vulnerabilities in agricultural sector. In northeastern Bangladesh, people usually grow vegetables in late winter and they are less concern to grow vegetables in summer. Therefore, local productions partially meet the households demand (Sunny *et al.*, 2019a). Uddin *et al.* (2009) reported that the daily requirements of vegetables were about 220 g but per capita consumption of vegetables in Bangladesh was only 50 g. Now, the daily per capita vegetables consumption in the rural areas is 194 g, which includes potato and leafy vegetables (Rahman and Islam, 2012). The poor people mostly intake potato and aroids as vegetables from local market during this period. Hence, the marginal community especially women and children are suffering with hidden hunger due to nominal intake of vitamins and minerals from plant sources. Micronutrient deficiency is a vital public health concern, affecting an estimated 2 billion people worldwide (Islam *et al.*, 2018b). Nelson *et al.* (2018) predicted that many regions would continue to have critical micronutrient inadequacy using a range of biophysical and socioeconomic scenarios towards 2050.

Seasonal vegetables lead the percentage of horticultural product. Vegetable farmer earned more than the farmer cultivated cereal crops (Weinberger and Lumpkin, 2005). Vegetable is important both from nutritional and financial point of view. Its contribution toward the food security in Bangladesh is also mentionable (Sunny *et al.*, 2020d). However, the availability of vegetable is only about 1/5th of the recommended requirement of 200 g/person/day (BBS, 2013). Vegetables play a crucial role in ensuring food and nutritional security, but they are highly perishable and their price hike due to frequent occurrence of natural calamities like heavy rain, flood, storm, drought and other climatic hazard make it untouched to the climate vulnerable poor communities in Bangladesh (Islam *et al.*, 2016; Sunny, 2017a; Sunny, 2017b; Islam *et al.*, 2018c; Sunny *et al.*, 2018). Vegetables are known as protective food as they supply essential nutrients, vitamins and minerals to the human body and are the best resource for overcoming micronutrient deficiencies (Kumari *et al.*, 2018; Sunny *et al.*, 2019a).

Vegetables are generally sensitive to environmental extremes. High temperatures and limited soil moisture are the major causes of low yields as they greatly affect several physiological and biochemical processes like reduced photosynthetic activity, altered metabolism and enzymatic activity, thermal injury to the tissues, reduced pollination and fruit set etc.(Kumari *et al.*, 2018). Climate change may have more effect on small and marginal farmers, particularly who are mainly dependent on vegetables (FAO, 2009; Sunny *et al.*, 2019b). Vegetable production is threatened by heavy rainfall and floods that can occur the spread of water-borne pathogens easier (Pautasso *et al.*, 2012; Sunny *et al.*, 2019b). Under changing climatic situations, crop failures, shortage of yields, reduction in quality and increasing pest and disease problems are common, which render the vegetable cultivation unprofitable (Koundinya *et al.*, 2014). IFAD (International Fund for Agriculture Development) has reported in 2009, that climate change could put 49 million additional people at risk of hunger by 2020, and 132 million by 2050 (Devendra, 2012). According to the definition of UNFCCC (2005), climate change resilient technology or adaptation technology means “the application of technology in order to reduce the vulnerability, or enhance the resilience, of a natural or human system to the impact of climate change”. Technologies can be categorized into two different types, such as, hard and soft technology. The hard technologies include the equipment and infrastructure while the soft technologies include management practice and institutional management (Christiansen *et al.*, 2011).

Many homestead areas from small to large farmers of Bangladesh remain fallow or unutilized, which is a common phenomenon (Islam *et al.*, 2017). There is a chance to bring these homesteads under vegetable production round the year including growing and/or management of quick growing fruit trees in a scientific way (BARI, 2011; 2012). The fresh vegetables and fruits produced in the homestead can contribute more by providing increased opportunities for economic empowerment, household food security, and access to nutrition round the year and conservation of the natural environment. Several studies have suggested that home gardens could be an option for food and nutritional security in disaster and relevant post-crisis situations (Galhena *et al.*, 2012; Wanasundera, 2006). Mitchell and Hanstad (2004) reported that home garden provided multiple social benefits such as enhancing food and nutritional security, empowering women, promoting social justice and equity, preserving indigenous knowledge and culture etc.

Suchana is the DFID and EU funded nutrition project that has been working at Sylhet since 2015. The homestead vegetable production intervention of Suchana project is contributing to reduce malnutrition keeping availability of nutrient rich vegetables throughout the year. Homestead based vegetable production intervention is disrupted every years due to heavy rainfall and flood. In that circumstance, Suchana project had taken an initiative to set an experiment on tower gardening in low-lying areas of Sylhet. However, Suchana program supported by its technical partner WorldFish Bangladesh carried-out the experiment on tower gardening technology with two major objectives: (a) to develop year round vegetables production technology for low-lying areas of Bangladesh, (b) to select an ideal climate smart technology (tower gardening) for vulnerable climate prone communities in Bangladesh.

Methodology

The study was carried out in Sylhet and Moulvibazar district during *kharif* season in 2017. Total 24 program participants were engaged for the study at Bishawnath, Osmaninagar & Sylhet Sadar under Sylhet and Moulvibazar Sadar, Kamalgonj, Kulaura and Barlekha Upazila under Moulvibazar district, respectively. The study plots were selected in low and inundated land and pond dyke of homestead. Each plot of every program participants occupied 20 sq. meter area with trellis and tower structure. This was a Randomized Complete Block Design (RCBD) with three replications.

Fig. 1. Tower garden preparing in low lying area.

Treatment: Tower gardening is a cylindrical like structure that makes with bamboo, brick chips, water hyacinth, soil, compost or organic fertilizer and special exhibition of vertical garden to produce vegetables round the year (Fig. 1). Two factors had been considered for this study.

Factor A: Tower size: To grow vegetables there were two types of tower structure. i) Medium size tower (T_1): This was medium size tower. The diameter of the structure was 4.5 ft with 5 ft height. ii) Small size tower (T_2): This was comparatively smaller than medium one with 3 ft diameter and 4 ft height.

Factor B: Growing media protecting materials of tower garden: Though the study area was in low-lying area, so two types media protecting materials were used to protect wash out of the medium. i) Plastic Bag (S_1): It was a simple plastic bag that usually used in poultry and fish feed industry. ii) Bamboo mat (S_2): Another protecting material made with bamboo.

Growing media: For uniform growth of vegetables a common media was prepared mixing with soil (50%), rotten water hyacinth (10%) and cow dung/compost (40%). A little amount of chemical fertilizer (i.e. TSP 250 g and MoP 125 g) was mixed thoroughly to prepare the growing media but 200 g urea was also used in two splits at 30-35 days and 45-50 days after transplanting.

Vegetables Types*:* Climbers vegetables (i.e. bottle gourd and bitter gourd) and herbaceous vegetables (i.e. kangkong, Indian spinach, red amaranth and okra) were used to conduct the study.

Sowing/transplanting: Usually all cucurbits seeded directly in favorable environment, hence the initiatives were to grow vegetables in adverse climatic condition specifically during the period of heavy rainfall. To minimize the situation, 10-15 days old seedlings of climber's vegetables were used through growing seedling in 10 x 4 sq. cm nursery poly bags mixing of normal top soil and sand mixture. The seedlings were transplanted on top of tower in afternoon followed by watering. Total six and eight cucurbits seedlings were transplanted on small and medium tower respectively. A few amounts of red amaranth & okra seeds also sow on top of the towers. Indian spinach & kangkong seedlings were transplanted around the tower. Irrigation was done based on rainfall and plant requirements. The seedlings transplanting was done in 15^{th} August 2017 and harvesting started from October 2017 and completed on 3^{rd} week of December 2017. Sex pheromone trap and detergent solution were used to control fruits flies and other pests. All the yield data were recorded using a predefined record book and analyzed statistically by using Statistical Tool for Agricultural Research (STAR) software. Mean separation were done following Turkey's Honest Significant Difference (HSD) test at 0.05 level of probability.

Results and Discussion

The aim of the study was to explore a climate smart technology in low-lying area for year round especially in *kharif* season, which is technically feasible, economically viable and community acceptable.

Effect of tower size and soil protecting materials on vegetable production

The effects of tower size and growing media protecting materials on the yield of vegetables are described below.

Table 1. Effect of tower size on vegetable production and its value.

Treatment	Production (Kg 20 m^{-2})	Sale value (BDT 20 m^{-2})	Production (t ha^{-1})	Sale value (Lac BDT ha^{-1})
T_1	76.55^{a}	1762.88^{a}	38.27^{a}	88.15^{a}
T_2	50.49^{b}	1155.29^{b}	25.24^{b}	56.87^{b}
Mean	63.52	1459.08	31.76	72.51
CV (%)	6.06	6.56	6.06	6.71

T_1 = Medium size tower, T_2 = Small size tower, Means with the same letters in a column are not significantly different at 5% level of probability.

Effect of tower size on vegetable production and its value

The findings showed that vegetable production was significantly influenced by the effect of tower size like Medium (T_1) and Small (T_2) (Table 1). The Medium size tower (T_1) gave the highest production (76.55 kg tower^{-1} and 38.27 t ha^{-1}) of vegetables whose sold value was BDT 1762.88 and BDT 88.15 Lac, respectively. In case of small tower (T2) vegetable production recorded (50.49 kg tower^{-1} and 25.24 t ha^{-1}) whose value was BDT 1155.29 and BDT 56.87 Lac.

Table 2. Effect of soil protecting materials on vegetable production and its value.

Treatment	Production (Kg 20 m^{-2})	Sale value (BDT 20 m^{-2})	Production (t ha^{-1})	Sale value (Lac BDT ha^{-1})
S_1	71.62^{a}	1661.58^{a}	35.81^{a}	83.08^{a}
S_2	55.41^{b}	1256.58^{b}	27.71^{b}	61.93^{b}
Mean	63.52	1459.08	31.76	72.51
CV (%)	6.06	6.56	6.06	6.71

S1 = Plastic bag for soil protecting materials, S2 = Bamboo mat for soil protecting materials, Means with the same letters in a column are not significantly different at 5% level of probability

Effect of soil protecting materials on production and sale value

The result in the Table 2 showed that the production of vegetables was significantly influenced by the effect of different soil protecting materials (S_1= Plastic bag), (S_2= Bamboo mat). The plastic bag (S_1) gave the highest production (71.62 kg tower^{-1} and 35.81 t ha^{-1}) of vegetable whose sold value was (BDT 1661.58 and BDT 83.08 Lac), respectively. However, in case of bamboo mat (S_2) production was recorded (55.41 kg tower^{-1} and 27.71 t ha^{-1}) whose value was (BDT 1256.58 and BDT 61.93 Lac), respectively.

Table 3. Combined effect of tower size and soil protecting materials on vegetable production and its value.

Treatment	Production (Kg 20 m^{-2})	Sale value (BDT 20 m^{-2})	Production (t ha^{-1})	Sale value (Lac BDT ha^{-1})
T_1S_1	84.35^{a}	1968.50^{a}	42.17^{a}	98.43^{a}
T_1S_2	68.74^{b}	1557.25^{b}	34.37^{b}	77.86^{b}
T_2S_1	58.89^{c}	1354.67^{c}	29.45^{c}	67.73^{c}
T_2S_2	42.08^{d}	955.92^{d}	21.04^{d}	45.99^{d}
Mean	63.52	1459.08	31.76	72.51
CV(%)	6.06	6.56	6.06	6.71

Means with the same letters in a column are not significantly different at 5% level of probability.

Combined effect of tower size and soil protecting materials on vegetable production and sale value

From the findings in Table 3 showed that the production of vegetables was significantly influenced by the combined effect of different size tower (T_1 & T_2) and soil protecting materials (S_1 & S_2). The highest vegetable production (84.35 kg tower^{-1}) and (42.17 t ha^{-1}) was recorded in medium tower with plastic bag (T_1S_1) whose sold value was BDT 1968.50 tower^{-1} and BDT 98.43 Lac ha^{-1}, respectively. The lowest production of vegetables (42.08 kg tower^{-1} and 21.04 t ha^{-1}) was recorded in small tower with bamboo mat (T_2S_2) and sold value was BDT 955.92 tower^{-1} and BDT 45.99 Lac ha^{-1}, respectively. In case of medium tower with bamboo mat (T_1S_2) combination the production was 68.74 kg tower^{-1} and 34.37 t ha^{-1} followed by small tower with plastic bag (T_2S_1) 58.89 kg tower^{-1} and 29.45 t ha^{-1}, respectively.

The vegetable production mainly depends on soil nutrient and environmental condition (Sunny *et al.*, 2019a). In case of medium tower, the production found higher than small tower because of medium tower contains higher nutrient. Besides, those soil-protecting materials also have effect on vegetable production and incase of plastic bag production recorded higher than bamboo mat. The reason of the more production in plastic bag compare than bamboo mat due to minimum nutrient loss through leaching (Celik *et al.*, 2010). According to the findings of Celik *et al.* (2010), normal soil contains higher organic matter, which increases the fertility of alkaline soil. Tower gardening is a suitable technology for climate prone areas of Bangladesh that can produce up to 100 kg vegetables tower^{-1} that worth 3000 taka (USD 38.49) and could be multiplied 3 or 4 times a year (Hossain *et al.*, 2015; Sunny *et al.*,2018). Generally there were two vegetable growing season in Bangladesh i.e. winter and *kharif*. And the experiment was conducted in *kharif* season where different leafy and fruity vegetables was grown like red amaranth, Indian spinach, kangkong, okra, bottle gourd and bitter gourd. The fruity vegetable production was the highest compare to leafy vegetables due to vegetable weight and sold value was also higher (Sunny *et al.*, 2018). In *kharif* season vegetable production was difficult and usually price value remains higher than winter so the collective sale value was also satisfactory.

In Bangladesh most of the vegetables were cultivated in the *rabi* (October to February, the main vegetable growing season) and *kharif-1* (March to June) seasons (Kuddus *et al.*, 2018. In monsoon season (July to September), the vegetable supply in the market was very limited due to lack of appropriate technologies for growing vegetables. (Biswas, 2012, Sunny *et al.*, 2019a).

Cost benefit and sensitivity analysis

Analysis of benefit cost ratio was calculated based on tower size and using materials. From the result of Table 4 the highest gross margin (BDT 1968), net profit (BDT 1568) and BCR (2.85) were recorded in medium tower with plastic bag. Whereas the lowest gross margin (BDT 955), net profit (BDT 605) and BCR (1.73) were found in case of small tower with bamboo *mat* (Table 5). Islam *et al.* (2003), Khan *et al.* (2009), Berning *et al.* (2008) and Talukder *et al.* (2000) found that the number of varieties and vegetable production was three times higher in the developed garden than traditional garden and child consumption was also 1.6 times higher. Alam (2011) documented that farmers obtained their main staple root crops from home gardens in Bangladesh.

Table 4. Cost benefit and sensitivity analysis of a medium tower garden.

Materials used to protect growing media	Situation	Total cost per tower (BDT)	Gross margin (BDT)	Net profit (BDT)	BCR
Plastic bag	Practically	550	1968	1568	2.85
	Decrease the total yield or price of vegetables				
	5% Level	550	1870	1320	2.40
	10% Level	550	1771	1221	2.22
Bamboo chatai	Practically	500	1557	1057	2.12
	Decrease the total yield or price of vegetables				
	5% Level	500	1479	979	1.96
	10% Level	500	1401	901	1.81
Average	Practically	525	1763	1238	2.36
	Decrease the total yield or price of vegetables				
	5% Level	525	1675	1150	2.19
	10% Level	525	1587	1062	2.02

Table 5. Cost benefit and sensitivity analysis of a small tower garden.

Materials used to protect growing media	Situation	Total cost per tower (BDT)	Gross margin (BDT)	Net profit (BDT)	BCR
Plastic bag	Practically	400	1354	954	2.39
	Decrease the yield or price of vegetables				
	5% Level	400	1286	886	2.22
	10% Level	400	1219	819	2.05
Bamboo chatai	Practically	350	955	605	1.73
	Decrease the yield or price of vegetables				
	5% Level	350	907	557	1.60
	10% Level	350	860	510	1.46
Average	Practically	375	1155	780	2.08
	Decrease the yield or price of vegetables				
	5% Level	375	1097	722	1.93
	10% Level	375	1040	665	1.78

Disposal pattern of harvested vegetables from tower garden

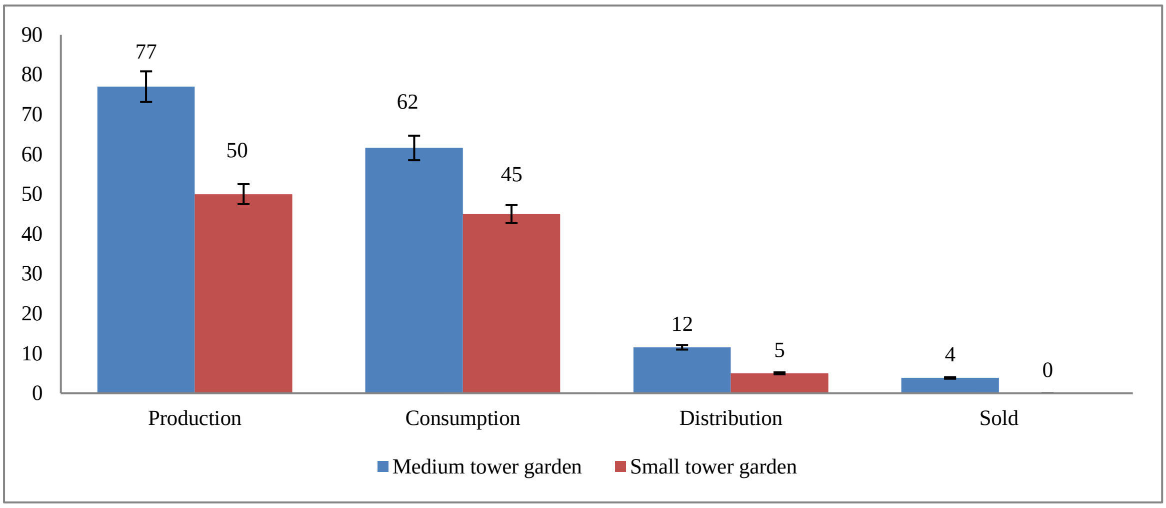

Fig. 2. Disposal pattern of harvested vegetables.

From the result, it was observed that total 77 kg vegetables harvested from medium size tower, among them consumed 62 kg (80%), distributed 12 kg (15%) and sold 4 kg (5%), respectively. Whereas in small tower consumed 45 kg (90%), distributed 5 kg (10%) and no sold from total 50 kg harvested vegetables (Fig. 2). Khan *et al.* (2009) and Islam *et al.* (2003) asserted that farmers consumed their harvested vegetables then sold and distributed the spare amount to other to strengthen social relation.

Conclusions

Climatic shocks adversely affect in Suchana communities as well as Sylhet where irregular and uncertain heavy rainfalls occurs frequently. The peoples living in *haor* region exhausted with inundation in every year. Tower gardening technology could be an effective and better option to produce vegetables during monsoon; eventually it is a good system of vegetables production in winter also. This also could be treated as women friendly technology due to its feasibility in homestead areas. The finding of the study could also be replicated in the coastal and other climate prone areas of the country. However, there is scope for further research using big size tower with short durable high value crops to search the commercial possibility of tower gardening technology.

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References

Alam, A. 2011. Effects of forest management and climate change on energy biomass and timber production with implications for carbon stocks and net CO2 exchange in boreal forest ecosystems. Dissertation Forestales 117. 88p.

BARI. 2011. Annual Research Report (2010-11) of On-Farm Research Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701, Bangladesh. pp. 303-323.

BARI. 2012. Annual Research Report (2011-12) of On-Farm Research Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701, Bangladesh. pp. 179-209.

BBS. 2013. Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Bangladesh Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. 468p.

Berning, C., Bradley, C., Sirman, K. and Sosa. 2008. Homestead Food Production in Barisal, Bangladesh: Capstone report. MA Candidates, International Development Studies, The Elliott School of International Affairs, The George Washington University, USA. 79p.

Biswas, S.C. 2012. Vegetable cultivation in the monsoon season in Bangladesh. Vegetable Research, BRAC Agricultural Research & Development Centre, Bangladesh, Issue 15. pp. 1-3.

Celik, H., Katkat, A.V., Asik, B.B. and Turan, M.A. 2010. Effect of humus on growth and nutrient uptake of maize under saline and calcareous soil conditions. *Agric.* 97(4): 15-22.

Christiansen, L., Olhoff, A. and Traerup, S. 2011. Technologies for Adaptation: Perspectives and Practical Experiences. Roskilde, Denmark. United Nations Environment Programme Rise Centre on Energy, Climate and Sustainable Development. Technical Univ. of Denmark. Risoe National Lab. for Sustainable Energy. UNEP Risoe Centre on Energy, Climate and Sustainable Development, Roskilde (Denmark). 144p.

Devendra, C. 2012. Climate Change Threats and Effects: Challenges for Agriculture and Food Security. ASM Series on Climate Change. Academy of Sciences, Malaysia, Kuala Lumpur. 56p. ISBN 978-983-9445-82-4.

FAO. 2009. Global agriculture towards 2050. Issues Brief. High level expert forum. Food and Agriculture Organization, Rome, Italy. pp. 12 -13.

Galhena, D.H., Mikunthan, G. and Maredia, K.M. 2012. Home Gardens for Enhancing Food Security in Sri Lanka. *Farming Matters*. 28(2): 12.

Hossain, E., Nurun Nabi, S.M. and Kaminski, A. 2015. Vertical agriculture: Suspended horticulture in towers. Penang, Malaysia: WorldFish. Program Brief. 29p.

Islam, F., Akkas Ali, M. and Ashraf, M. 2003. Homestead Vegetable Gardening: A Means of Homestead Food and Nutrition Security for Marginal Farmers. *Bangladesh J. Agril. Res.* 28(2): 261-270.

Islam, M.M., Islam, N., Mostafiz, M., Sunny, A.R., Keus, H.J., Karim, M., Hossain, M.Z. and Sarker, S. 2018b. Balancing between livelihood and biodiversity conservation: A model study on gear selectivity for harvesting small indigenous fishes in southern Bangladesh. *Zool. Ecol.* 28(2): 86-93. https://doi.org/10.1080/21658005.2018.1429895

Islam, M.M., Islam, N., Sunny, A., Jentoft, S., Ullah, M.H. and Sharifuzzaman, S.M. 2016. Fishers' perceptions of the performance of hilsa shad (*Tenualosa ilisha*) sanctuaries in Bangladesh. *Ocean Coastal Manage.* 130: 309-316. https://doi.org/10.1016/j.ocecoaman.2016.07.003

Islam, M.M., Shamsuzzaman, M.M., Sunny, A.R. and Islam, N. 2017. Understanding fishery conflicts in the Hilsa sanctuaries of Bangladesh. *In:* Inter-sectoral governance of inland fisheries. Song AM, Bower SD, Onyango P, Cooke SJ, & Chuenpagdee R. (eds.), TBTI Publication Series, St John`s, NL, Canada. pp. 18-31.

Islam, M.M., Sunny, A.R., Hossain, M.M. and Friess, D.A. 2018a. Drivers of Mangrove Ecosystem Service Change in the Sundarbans of Bangladesh. *Singapore J. Trop. Geo.* 39(2): 244-265. https://doi.org/10.1111/sjtg.12241

Islam, M.R., Cansse, T., Islam, M.S. and Sunny, A.R. 2018c. Climate change and its impacts: The case of coastal fishing communities of the Meghna river in south central Bangladesh. *Int. J. Marine Environ. Sci.* 12(10): 368-376. https://doi.org/10.5281/zendo.1474924

Khan, M.A.H, Yusuf Ali, M., Quayyum, M.A., Nazrul, M.I. and Hossain, M.J. 2009. Year Round Homestead Vegetables Production: A Means of Reducing Poverty and Nutritional Deficiency for Small Farm. *Bangladesh J. Agril. Res.* 34(1): 169-174. https://doi.org/10.3329/bjar.v34i1.5767

Koundinya, A., Palash, S. and Pandit, M.K. 2014. Impact of climate change on vegetable cultivation a review. *Int. J. Agric. Environ. Biotech.* 7(1): 145-155. https://doi.org/10.5958/j.2230-732X.7.1.020

Kuddus, M.A., Miah, M.A., Datta, G.C., Sarker, A.K., Alam, M.J., Hossain, M. and Hamid S.M.A. 2018. Participatory evaluation of orange-fleshed sweet potato varieties in Sylhet region. *Int. J. Nat. Soc. Sci.* 5(2): 42-49

Kumari, M., Verma, S.C. and Shweta. 2018. Climate change and vegetable crops cultivation: A review. *Indian J. Agril. Sci.* 88(2): 167–74.

Mitchell, R. and Hanstad, T. 2004. Small Home garden Plots and Sustainable Livelihoods for the Poor. Rome, Italy. 11p.

Nelson, G. Bogard, J., Lividini, K., Arsenault, J., Riley, M., Sulser, T.B., Mason-D'Croz, D., Power, B., Gustafson, D., Herrero, M., Wiebe, K., Cooper, K., Remans, R. and Rosegrant, M. 2018. Income growth and climate change effects on global nutrition security to midcentury. *Nature Sustain.* 1: 773-781. https://doi.org/10.1038/s41893-018-0192-z

Pautasso, M., Doring, T.F., Garbelotto, M., Pellis, L. and Jeger, M.J. 2012. Impacts of climate change on plant diseases opinions and trends. *European J. Plant Path.* 133: 295–313. https://doi.org/10.1007/s10658-012-9936-1

Rahman, K.M.M. and Islam. M.S. 2012. Nutritional Status and Food Security of Farm Households under Different Land Use Patterns in Bangladesh. *J. Nutri.* 24-25: 49-64. https://doi.org/10.3329/bjnut.v24i0.14036

Salinger, M.J., Sivakumar, M.V.K. and Motha, R. 2005. Reducing vulnerability of agriculture and forestry to climate variability and change: workshop summary and recommendations. *Climatic Change.* 70: 341–362. https://doi.org/10.1007/s10584-005-5954-8

Sunny, A.R. 2017a. A review on the effect of global climate change on seaweed and seagrass. *Int. J. Fish. Aqu. Stud.* 5(6): 19-22.

Sunny, A.R. 2017b. Impact of oil Spill in the Bangladesh Sundarbans. *Int. J. Fish. Aqua. Stud.* 5(5): 365-368.

Sunny, A.R., Ahamed, G.S., Mithun, M.H., Islam, M.A., Das, B., Rahman, A., Rahman, M.T., Hasan, M.N. and Chowdhury, M.A. 2019b. Livelihood Status of the Hilsa (*Tenualosa ilisha*) Fishers: The Case of Coastal Fishing Community of The Padma River, Bangladesh. *J. Coastal Zone Manage.* 22(2): 469.

Sunny, A.R., Alam, R., Sadia, M.K., Miah, M.Y., Hossain, M.S., Hossain, M.J., Mofiz, M.S.B., Sazzad, S.A., Ashrafuzzaman, M. and Prodhan, S.H. 2020c. Factors Affecting the Biodiversity and Human Well-Being of an Ecologically Sensitive Wetland of North Eastern Bangladesh. *J. Coastal Zone Manage.* 23(1): 471.

Sunny, A.R., Islam, M.M., Nahiduzzaman, M. and Wahab, M.A. 2018. Coping with climate change impacts: The case of coastal fishing communities in upper Meghna hilsa sanctuary of Bangladesh. In: Babel, M.S., Haarstrick, A., Ribbe, L., Shinde, V., Dichti, N. (Eds.), Water Security in Asia: Opportunities and Challenges in the Context of Climate Change, Springer. pp. 1-9. http://www.springer.com/us/ book/9783319546117

Sunny, A.R., Islam, M.M., Rahman, M., Miah, M.Y., Mostafiz, M., Islam, N., Hossain, M.Z., Chowdhury, M.A., Islam, M.A. and Keus, J.H. 2019a. Cost effective aquaponics for food security and income of farming households in coastal Bangladesh. The *Egyptian J. Aqua. Res.* 45(1): 89-97. https://doi.org/10.1016/j.ejar.2019.01.003

Sunny, A.R., Masum, K.M., Islam, N., Rahman, M., Rahman, A., Islam, J., Rahman, S., Ahmed, K.J. and Prodhan, S.H. 2020a. Analyzing livelihood sustainability of climate vulnerable fishers: Insight from Bangladesh. *J. Aqua. Res. Dev.* 11(6): 593. https://doi.org/10.35248/2155-9546.19.10.593

Sunny, A.R., Reza, J., Anas, M., Hassan, M.N., Baten, M.A., Hasan, R., Monwar, M.M., Solaimoan, H. and Hossain, M.M. 2020b. Biodiversity assemblages and conservation necessities of ecologically sensitive natural wetlands of northeastern Bangladesh. *Indian J. Geo-Marine Sci.* 49(1): 135-148.

Sunny, A.R., Sazzad, S.A., Datta, G.C., Sarker, A.K., Ashrafuzzaman, M. and Prodhan, S.H. 2020d. Assessing Impacts of COVID-19 on Aquatic Food System and Small-Scale Fisheries in Bangladesh. Preprints.2020060143. https://doi.org/10.20944/preprints202006.0143.v1

Talukder, A., Saskia, de. P., Taher, A., Hall, A., Pfanner, R.M. and Bloem, M.W. 2000. Improving Food and Nutrition Security through Homestead Gardening in Rural, Urban and Peri-Urban Areas in Bangladesh. Helen Keller International, Bangladesh. 62p.

Uddin, M.J., Masud, A.T.M., Aktar, L., Rashid, M.A. and Haque, A. 2009. Improved Variety of Sweet Gourd and Production Technology (Booklet). Published by Bangladesh Agricultural research Institute, Gazipur, Bangladesh. pp. 1-18.

UNFCCC. 2005. Report on the Seminar on the Development and Transfer of Technologies for Adaptation to Climate Change: Note by the Secretariat. FCCC/SBSTA/2005/8. United Nations Framework Convention on Climate Change. p. 18.

Wanasundera, L. 2006. Rural Women in Sri Lanka's Post-Conflict Rural Economy. Colombo, Sri Lanka. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific Bangkok, Thailand. p. 43. http://www.fao.org/3/ag114e/AG114E00.htm

Weinberger, K. and Lumpkin, T.A. 2005. Horticulture for poverty alleviation—the unfunded revolution. Shanhua, Taiwan: AVRDC – The World Vegetable Center, AVRDC Publication No. 05-613, Working Paper No. 15. 20p.