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Impact and adaptation strategies of climate change in agricultural extension system in Bangladesh

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Facing the adverse effects of climate change is one of the biggest challenges for the country of Bangladesh. As a low lying downstream riparian country (70 percent of land area is 5 m or less above sea level), Bangladesh is one of the country's most vulnerable to extreme climate events and the impact of climate change, from both flooding and sea water intrusion. Climate change is already affecting agricultural production with most alarming adverse effects in Bangladesh. Extreme weather conditions have changed the overall distribution of yearly rainfall, shifted cropping seasons, increased infestation of crops by pests and diseases, made the water-table decline in the Barind tract and some other areas. At the same time, demand for food is rapidly increasing with the population. Enhancing resilience is a major challenge not only for agricultural sustainability but also for the substantial non-farm rural economy. Hence, the development of climate resilient technology and adaptation strategies for food security, economic stability, and livelihood security of the people are crucial. In this article, an attempt was made to describe the threat of climate change, to highlight it's the mitigation process, and to present practical implication for extension systems in facing the challenge of climate.

Keywords: Climate change, extension modality, food security, rural economy.

INTRODUCTION

"Climate change is occurring and is very likely caused by human activities and poses significant risks for a broad range of human and natural systems". Many independent scientific organizations have released similar statements, both in the United States and abroad. Global average temperatures have increased more than 1.4^{0}C over the last 100 years. In fact, according to the National Oceanic and Atmospheric Administration (NOAA, 2010), the decade from 2000 to 2010 was the warmest on record, and 2010 was tied with 2005 as the warmest year on record. Rising global temperatures have also been accompanied by other changes in weather and climate.

Many places have experienced changes in rainfall resulting in more intense rain, as well as more frequent and severe heat waves. The planet's oceans and glaciers have also experienced changes; oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising. Jwakyung et al., (2014) reported that moderately high temperature influences much greater to photosynthesis and carbohydrate production than on plant biomass and mineral uptake. Drought is one of the major environmental factors which limits the quantity and quality of rice grains and also significantly influences their chemical composition (Kyong and Chang, 2015).

All of these changes are evidence that our world is getting warmer. Carbon dioxide is a necessary ingredient for plants to perform photosynthesis and a critical component of our atmosphere. The excess carbon dioxide we are adding to the atmosphere increases global temperatures, leading to climate changes that can harm plants, animals, and humans. Changing the average global temperature by even a degree or two can lead to serious consequences around the globe. For about every 2°C of warming, we can expect to see 1) 5-15% reductions in the yields of crops currently grown, 2) 3-10% increases in the amount of rain falling during the heaviest precipitation events, which can increase flooding risks, 3) 5-10% decreases in stream flow in some river basins, including the Arkansas and the Rio Grande, 4) 200-400% increases in the area burned by wildfire in parts of the western United States. Many of the extreme precipitation and heat events that we have seen in recent years are consistent with what we would expect given this amount of warming. Scientists project that Earth's average temperatures will rise between 0.3℃ to 4.8℃ by 2100 (IPCC, 2013).

Climate change is an environmental issue which has significant implication on poverty and inequality. The pattern and behavior of climate including variability and extreme events play a significant role in freshwater availability, agricultural productivity, function of natural eco system and biodiversity, human health and livelihood of the people (Policy Study on The Probable Impacts of Climate Change on Poverty and Economic Growth and The options of Coping with Adverse Effects of Climate Change in Bangladesh, 2009). These characteristics of climate either create favorable conditions for a system to function better or impose risks on a system or increase its vulnerability. Therefore, economic growth and the performance of a nation or society depend on, to a large extent, the behavior of climate.

A number of papers (Skoufias et al., 2011; Thurlow et al., 2009) have recognized the changing climate as one of the emerging issues of poor people being enabled to participate in growth, poverty, and inequality. Poor people are generally the most vulnerable to climate change as they live in disaster prone and remote areas where they have little capacity to adapt to stresses. They are also more dependent on ecosystem functions for their livelihood. Any impact that climate change has on natural system therefore threatens employment and income generation. Moreover, livelihood, food intake, health, and education are also affected by climate change.

Impact of climate change in Bangladesh agriculture and food security

Water vapor, carbon dioxide, methane, and ozone in decreasing order of contribution are mainly responsible for temperature increase. At the same time, the country is frequently affected by floods, droughts, cyclones, and soil salinity due to climate change. Changes in the atmospheric concentrations of these greenhouse gases can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a measure of the influence a perturbation has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system (IPCC, 2013).

In Bangladesh, about 1 million ha of the coastal region are saline due to sea water. But there are very few varieties that are tolerant to salinity. Droughts affect 2.5 million ha annually in kharif and 1.2 million ha in the dry season. Kharif drought affects T. *aman* rice severely. The devastating flood of 2004 inundated 40 districts and caused considerable loss of crops and human lives. But a very limited number of agricultural technologies are available that are tolerant to flood and drought.

Due to the rise in temperature, crop production will be reduced by about 30%. Climate change, especially temperature rise, would decrease the yield of *boro* rice by 55-62% and wheat by 61% by 2050 in Bangladesh (New Age, 2008).

The impact of climate change is predicted to adversely affect the Bangladesh agriculture and its economy. As a low lying downstream riparian country, 70 % of land area in Bangladesh is 5 m or less above sea level. Climate change induced 1.5 m rise of sea level will affect 17 million (15%) population and inundate up to 22,000 km^2 (16%), which will lead to migration in upland areas, decreased fresh water availability in coastal areas, and increase of natural calamities, drought, salinity (soil and water) etc. Climate change threatens production, stability, and productivity. In many areas of the world where agricultural productivity is low and the means of coping with adverse events are limited. Climate change is expected to reduce productivity to even lower levels and make production more erratic (Stern

Review, 2006; Cline, 2007; Fisher et al., 2002; IPCC, 2007).

Long-term changes in the patterns of temperature and precipitation, which are part of climate change, are expected to shift production seasons, change pest and disease patterns, and modify the set of feasible crops; affecting production, farm income, and ultimately, livelihoods and lives. Human activities are the driving force for the loss of biodiversity at an unprecedented rate, up to 1000 times of the natural rate of species loss. Climate change has become a major driver of biodiversity loss as well as a serious challenge to agriculture, whose response to adapt will draw upon the genetic diversity of crops and livestock and the services provided by other components of agricultural diversity.

Climate is the most important environmental factor affecting agricultural production and is also now significantly influenced by agriculture. About 24% of the earth's land surface is covered by cultivated systems and the cumulative impact of worldwide agricultural practices on the global climate is significant. Global agriculture is estimated to account for about 20% of total anthropogenic emissions of GHG (UNEP, 2009).

Causes of Climate Change

It is generally considered that there are four major causes of climate change, namely: 1) astronomical causes, 2) volcanic eruptions, 3) variations in solar output, and 4) anthropogenic changes in earth's environment. The intergovernmental panel on climate change (IPCC) says that human activity is the main cause of the changes seen in climate through activities that cause emissions of greenhouse gases (GHG) (mainly consist of carbon dioxide, water vapor, methane and nitrous oxide). Studies of long-term climate change have discovered a connection between the concentrations of carbon dioxide in the atmosphere and mean global temperature.

Carbon dioxide is one of the most important gases responsible for the greenhouse effect. These greenhouse gases can alter the energy balance of the earth by being able to absorb long wave radiation emitted from the earth's surface. The net results of this process and the re-emission of long waves back to the earth's surface increase the quantity of heat energy in the earth's climatic system. Human activity is changing the amount of greenhouse gases (GHG) in the atmosphere in three important ways, namely;

Burning fossil fuels:

Carbon dioxide is one of the main GHGs and contributors to the greenhouse effect. When fossil fuels such as coal, oil, and gas burn, they release GHGs. Anyadike (2009) stated that, through energy consuming like heating homes and buildings, transportation and cooking of food, traveling (for example, by car, plane, bus and train), treating water to make it drinkable, heating it and piping it into homes, manufacturing fridges, gas flaring, bush burning etc., people induce the emission of carbon dioxide into the atmosphere. Since the industrial revolution, which began in the 18th century, the amount of CO_2 in the atmosphere has increased by 35%.

Niger Delta region of Nigeria is reported to have over one hundred and twenty-three gas flaring sites making Nigeria one of the highest emitters of GHGs in Africa (Akinro et al., 2008). A recent study by the World Bank (2008) revealed that Nigeria accounts for roughly one-sixth of worldwide gas flaring, Nigeria flares about 75% of her gas.

Deforestation:

Deforestation, where forests are cut down faster than they are replaced, is a major contributor to climate change. It accounts for 20 percent of the world's carbon emissions (more than the transport sector produces). Deforestation makes such a huge contribution to carbon emissions because trees absorb CO_2 as they grow. If there are fewer trees left to absorb CO_2, then CO_2 will build up in the atmosphere. The agriculture and industry that replace the forests not only damage the earth's ability to absorb CO_2, but also hey often cause an additional problem by producing carbon emissions of their own. In Nigeria, the primary tropical forest cover has been decimated by 97%, mostly since 1990. The remainder is supposedly protected in Cross Rivers National Park and by a two-year logging ban imposed in November 2008. The country's broader forest cover was estimated at just over 12% in 2005, being depleted at a rate of 3.3% per annum. The main cause is the demand for wood fuel.

A Growing World Population:

As the world's population grows, there are more people who need food, livestock, and energy. This increased demand leads to increased emissions.

Against the backdrop of a declining natural resource base and environmental change, food production in the coming decades will need to increase. Genetic diversity within crop and livestock species will be an invaluable resource to enable adaptation to changing conditions through breeding and bringing more species under cropping culture. Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity and lower variability in the face of climate risk and risks of an agro-ecological and socio-economic nature. In order to stabilize output and income, production systems must become more resilient, i.e. more capable of performing well in the face of disruptive events.

A more productive and resilient agriculture requires transformations in the management of natural resources (e.g. land, water, soil nutrient, and genetic resources) and higher efficiency in the use of these resources inputs for production. Transitioning to such systems could also generate significant mitigation benefits by increasing carbon sinks, as well as reducing emissions per unit of agricultural product (Ifeani-Obi et al., 2012; Anonymous, 2011).

Important categories of agricultural emissions

Carbon dioxide (CO_2):

In general, fossil fuel use is the primary source of CO_2. The way in which people use land is also an important source of CO_2, especially when it involves deforestation. CO_2can also be emitted from direct human-induced impacts on forestry and other land use, such as through deforestation, land clearing for agriculture, and degradation of soils.

Methane (CH_4):

Agricultural activities, waste management, energy use, and biomass burning all contribute to CH_4emissions.

Nitrous oxide (N_2O):

Agricultural activities, such as fertilizer use (primary source) and biomass burning, are substantial sources of N_2O emissions.

Fluorinated gases (F-gases):

Industrial processes, refrigeration, and the use of a variety of consumer products contribute to emissions of F-gases, which include hydro fluorocarbons (HFCs), per fluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

Techniques of mitigating adverse effect of greenhouse gases

Some agricultural techniques can be followed to reduce the greenhouse gas footprint of agriculture. Cropping systems, which maximize the absorption of atmospheric carbon, minimize the emission of CO_2, NO_2 and methane and increase organic matter into soil. This can be achieved by forestation, inclusion of pulse crops in the cropping pattern, effective use of nitrogen fertilizer to reduce NO_2 emission, incorporation of compost (green manure, cow dung, oil cake, etc.), application of potash fertilizer to restrict CH_4 (Methane) emission undersoil anaerobic conditions, and use of minimum tillage practices to reduce carbon emissions in suitable cases.

Coping strategies in the face of climate change

Sustainable agriculture (such as bound or dikes, green manure, crop rotation, incorporation of stubbles, ditches, terraces, barriers, mulch, legumes, plowing parallel to the slope, no-burn, and zero-tillage etc.) can mitigate climate change through carbon sequestration and offer a genuinely low GHG emission alternative. In fact, we should follow such agricultural techniques so that crops absorb the maximum atmospheric carbon. These can be achieved by 1) developing resilient and sustainable agro-technologies and 2) promoting these technologies adopting appropriate extension approaches.

Building resilience for reducing vulnerabilities and increasing adaptive capacity

To a great extent, increasing resilience can be achieved by reducing vulnerabilities and increasing adaptive capacity. This can be achieved by reducing exposure, reducing sensitivity, and increasing adaptive capacity, for every type of risk.

Three Ways to Build Systemic Resilience in Agriculture

In a first approximation, we can identify the following three ways to build resilience:

Reduce exposure:

There is a fundamental difference between climatic and non-climatic shocks in this regard because most of the stresses non-climatic can be reduced at the source, or limited in their extensions, contrary to climatic shocks.

Reduce the sensitivity of systems to shocks:

Sensitivity to drought can, for instance, be reduced by using drought-resistant varieties (Binadhan-7).

Increase adaptive capacity:

This includes considering the modifications of a system taking into account all the potential shocks and changes such as compensating, cumulative, or exacerbating effects.

The second approximation is that there is a need to consider that strengthening real life resilience has to be done at the same time as the shock occurs because they occur all the time. Here is where we can separate between different types of resilience-building actions, ex-ante or preparedness based on forecasts (A), during shock (B) and ex-post or based on actual results (C):

A. Before the shock:

Increasing ex-ante actions, for example, through putting in place systems for the early detection of emerging risks or through the reduction or elimination of a specific risk.

B. During the shock:

Including safety nets that ensure the affected agents (farmers, communities, small-scale food processors and poor consumers) can benefit from continuing access to food and adequate diets and keep their asset levels and means of livelihood.

C. After the shock:

Helping systems to recover and build adaptive capacity. Actions can be pursued that progressively reduce the effect of the previous shock, reduce the exposure and sensitivity to future ones, and/or increase the adaptive capacity of a system to future shocks in a changing context (FAO/OECD, 2012).

Developing resilient and sustainable agro technologies

Resilient crop varieties which are tolerate heat, flooding, drought, disease and insect infestation, salinity and other threats. Similarly, environment friendly agro technologies are essential for sustainable agricultural production and, as proposed by the FAO, a climate smart agriculture (CSA) approach. Considering the agro-ecological conditions of Bangladesh, the following are recommendations for innovation: 1) Development of resilient crop varieties with high level of carbon absorption capacity, 2) Forestation, 3) Inclusion of pulse crops in the cropping pattern, 4) Effective use of nitrogen fertilizers to reduce NO_2 emission, 5) Incorporation of green manure, compost, cow dung, oil cake etc, in the soil for increasing carbon in the soil and increasing soil health, 6) Application of potash fertilizer for restricting CH_4 (Methane) emission in anaerobic conditions, 7) Use of minimum tillage practices for crop cultivation to reduce carbon emission in suitable cases.

Extension strategies for diffusion and adoption

Extension has the mandate of transforming technologies among rural communities and farmers through dissemination of information that will improve or change their standard of living. With the emerging significant threat posed by climate change, the agricultural extension system in the country will need to address the following examples in order to overcome the militating effect of climate. First, creating awareness on issues of climate change- its effects and the adaptation options available to farmers. Secondly, the recognition of existing, farmer-developed, adaptive measures and practices by extension agents, policy makers, and researchers through farmer involvement. Thirdly, there is a need for change and expansion in the capacity and role of extension agents. Extension agents, as well as the entirety of extension services staff, need to be trained on issues of climate change. Extension strategies recommendations should be adopted for promoting CSA in the country. Emphasis should be placed on making extension services demand-driven. The concept of demand-driven extension services emphasizes the need to provide services that meet needs and priorities of farmers in the context of changing domestic and international environments for agriculture (Birner and Anderson, 2007).

Practical implications of demand-driven approach to extension system

Understanding the location-specific problem, targeting the solutions, and undertaking evidenced-based extension programs and their implementation are key factors to achieve extension objectives towards a successful transition to CSA.

Up-scaling of improved water management practices for increasing crop water productivity and cropping intensity in Barind area

The drought prone Barind area is very dry with uneven and scanty rainfall during the dry season. Farmers there grow long duration T. (Transplanting) *aman* rice which is harvested at the end of November or in early December. In drought, profile soil moisture depletes and sowing time of Rabi crops is also delayed. Moreover, having no surface water sources, farmers cannot grow Rabi crops and are then compelled to cultivate *boro* rice using the Barind Multipurpose Development Authority (BMDA)-developed deep tube well (DTW) irrigation water. This, on one hand, causes the land to remain fallow and unutilized and, on the other hand, excessive withdrawal of groundwater for irrigation causes declining of water-table during the dry season. The long term study named "Analysis of ground water-table declination and quest for sustainable water use in the north-western region (Barind area) of Bangladesh" demonstrated that of the water-table is declining alarmingly and it will double by 2030 in some areas and in all the areas by 2050 (Ali et al., 2012). Under the circumstances, the land should be brought under non-rice Rabi crop cultivation, or judicious amount of water should be used for rice cultivation.

Therefore, with the above views, adaptation trials were conducted using short-duration T. *aman* rice based non-rice cropping pattern to make the land free for timely sowing of Rabi crops and its successful cultivation with minimum irrigation by effective utilization of profile soil moisture and optimized water use for *boro* rice cultivation during 2010-2011. The two year average compiled results of this research on T. *aman* rice based on cropping patterns adaptation trials were very encouraging. The adaptation trial results revealed that the combination of T. *aman* (Binadhan-7/BRRI dhan33), Rabi (Chickpea/mustard/wheat), and Kharif-1 (Mung bean/sesame), using straw mulch in Rabi and Kharif-1 crops, was the best pattern for increasing cropping intensity, yield, and water saving in drought-prone Barind area. Benefit cost ratio (BCR) were 2.03, 1.81 recommended and existing patterns respectively (BINA, 2012). Above alternative cropping pattern was considered as the most profitable, environment friendly and water saving cultivation technique.

Up-scaling of transplanted aman variety, Binadhan-7 during 2012-13:

In transplanted *aman* season, a high yielding and short- duration rice variety Binadhan-7 was selected for up-scaling in the Barind area. Thirteen block farming's were carried out in Nachole and Gomostapur upazilla of Chapai Nawabganj district. Area of each block was 1.3 ha. Seedlings of 20-25 days were transplanted during the last week of July 2012. Fertilizers and other intercultural managements were followed as per recommendation. The rice was harvested on the last week of October 2012. The data recorded were yield per hectare, crop duration, overall performance, cost-benefit, and contact grower farmer's preference about the suitability of the variety and cropping sequence. The result of yield and maturity of the variety indicated that Binadhan-7 produced an average grain yield of 4.40 t ha^{-1} and maturity duration was 119 days (Table 1). Farmers were very much interested in Binadhan-7 due to its short maturity period and encouraging yield, which also facilitated water saving and profitable Rabi crop cultivation in proper time.

Table 1. Location-wise results of the variety Binadhan-7 demonstrated during 2012-13.

Upazilla	Locations name	Transplanting date	Harvesting date	Duration (days)	Yield (t ha^{-1})
Nachole	Hatbakoil	28-07-2012	30-10-2012	117	4.20
	Srirampur	24-07-2012	28-10-2012	119	4.8
	Ghion	25-07-2012	29-10-2012	120	4.20
	Cosba	9-07-2012	22-10-2012	127	4.15
	Cosba	13-07-2012	21-10-2012	123	4.18
	Takahara	17-07-2012	18-10-2012	117	4.80
	Mirzapur	19-07-2012	22-10-2012	119	4.60
	Nijampur	28-07-2012	4-11-2012	122	4.00
Gomostapur	Ishurpurganj	28-07-2012	31-10-2012	119	4.50
	Shagroil	24-07-2012	23-10-2012	117	4.76
	Sotodadpur	25-07-2012	25-10-2012	116	4.50
	Borodadpur	25-07-2012	22-10-2012	113	4.00
	Zinarpur	26-07-2012	28-10-2012	118	4.50
Average		09-28 July	21 Oct. to 04 Nov	119	4.40

Table 2. Location-wise performance of different rabi crops (wheat, mustard and check pea) demonstrated during 2012-13.

Upazilla	Locations	Crops	Sowing date	Harvesting date	Duration (days)	Irrigations number	Yield (t ha^{-1})
Nachole	Hatbakoil	Wheat	21 -11-12	27-03-13	126	2	3.30
	Srirampur	Wheat	21-11-12	26-03-13	125	2	4.19
	Ghion	Wheat	21-11-12	23-03-13	122	2	3.30
	Cosba	Mustard	25-11-12	16-02-13	85	2	1.80
	Cosba	Wheat	19-11-12	17-03-13	118	2	3.60
	Takahara	Wheat	18-11-12	22-03-13	124	2	3.60
	Mirzapur	Wheat & Mustard	23-11-12	18-03-13 15-02-13	116 84	2 2	3.20 1.50
	Nijampur	Chickpea	21-11-12	28-03-13	127	1	1.40
Gomostapur	Ishurpurganj	Wheat & Chickpea	14-11-12& 18-11-12	17-03-13 13-03-13	124 116	2 1	4.20 1.40
	Shagroil	Wheat & Chickpea	24-11-12& 20-11-12	31-03-13 17-03-13	127 118	2 1	3.90 1.50
	Sotodadpur	Wheat & Chickpea	20-11-12 & 14-11-12	25-03-13 16-03-13	124 122	2 1	4.20 1.50
	Borodadpur	Wheat	1-12-12	30-03-13	122	2	4.20
	Zinarpur	Wheat & Chickpea	20-11-12 & 22-11-12	20-03-13 16-03-13	121 114	2 1	4.20 1.50
Average		Mustard	23-25 Nov.	15-16 Feb.	84	2	1.65
		Wheat:	14 Nov.- 1 Dec.	17-31 March	123	2	3.81
		Chickpea	14 Nov- 21 Nov.	13-28 March	119	1	1.46

Table 3. Location-wise results of the variety mungbean (Binamoog-8) and sesame (Binatil-1) demonstrated during 2012-13.

Upazilla	Locations	Crops	Sowing date	Harvesting date	Duration (days)	Number of Irrigation (Pre/post sowing)	Yield (t ha^{-1})
Nachole	Hatbakoil	Mungbean	12-04-13	30-06-13	78	2	0.90
	Srirampur	Sesame	04-04-13	02-07-13	88	1	0.80
	Ghion	Mungbean	29-03-13	18-06-13	80	2	0.85
	Cosba	Mungbean	10-04-13	23-6-13	74	2	0.95
	Cosba	Mungbean	26-03-13	27-06-13	92	2	0.89
		Sesame	01-04-13	28-6-13	87	2	0.95
	Takahara	Mungbean	29-03-13	28-06-13	90	1	0.70
		Sesame	29-03-13	28-06-13	90	1	0.75
	Mirzapur	Mungbean	09-04-13	15-06-13	67	2	0.90
		Sesame	07-04-13	28-06-13	82	2	1.10
	Nijampur	Mungbean	26-03-13	20-06-13	85	1	0.85
Gomostapur	Ishurpurganj	Mungbean	25-03-13	30-06-13	96	2	0.79
		Sesame	25-03-13	01-07-13	97	2	1.10
	Shagroil	Mungbean	31-03-13	02-07-13	92	2	0.84
		Sesame	31-03-13	02-07-13	92	2	0.88
	Sotodadpur	Mungbean	24-03-13	20-6-13	87	1	0.79
		Sesame	24-03-13	28-6-13	95	1	0.65
	Borodadpur	Mungbean	19-02-13	05-05-13	74	2	0.85
		Sesame	19-02-13	30-05-13	99	1	0.76
	Zinarpur	Mungbean	25-03-13	15-05-13	82	1	0.83
		Sesame	25-03-13	02-07-13	98	1	0.88
Average		Mungbean	19 Feb-12 April.	5 May to 15 July.	83	2	0.93
		Sesame	19 Feb-7April.	30 May to 2 July.	92	1	0.84

Table 4. Financial analysis of year-round different cropping sequences demonstrated during 2012-13.

Patterns number	Crops	Yield(t ha^{-1})	Production cost (\$ ha^{-1})	Total Gross income (\$ ha^{-1})	Net Return (\$$ha^{-1}$)	BCR	Net income by pattern (\$ ha^{-1})	BCR by Pattern
I	**T. *aman***	4.40	879.43	1132.70	253.27	0.02	414.96	0.015
	Chickpea	1.05	518.79	692.19	173.40	0.02		
	Mungbean	0.77	517.11	505.40	-11.71	0.01		
II	**T. *aman***	4.40	879.43	1132.70	253.27	0.02	643.82	0.017
	Mustard	1.65	604.09	1006.35	402.26	0.02		
	Mungbean	0.77	517.11	505.40	-11.71	0.01		
III	**T. *aman***	4.40	879.43	1132.70	253.27	0.02	562.35	0.016
	Wheat	3.60	625.24	946.03	320.79	0.02		
	Mungbean	0.77	517.11	505.40	-11.71	0.01		
IV	**T. *aman***	4.40	879.43	1132.70	253.27	0.02	429.69	0.015
	Chickpea	1.05	518.79	692.19	173.40	0.02		
	Sesame	0.84	453.36	456.38	3.02	0.01		
V	**T. *aman* (Bina dhan-7)**	4.40	879.43	1132.70	253.27	0.02	734.83	0.017
	Mustard	1.65	604.09	1006.35	402.26	0.02		
	Sesame	0.84	453.36	456.38	3.02	0.01		
VI	**T. *aman***	4.40	879.43	1132.70	253.27	0.02	577.08	0.0016
	Wheat	3.60	625.24	946.03	320.79	0.02		
	Sesame	0.84	453.36	456.38	3.02	0.01		
Check	**T. *aman* (Shorna)**	4.50	923.87	1155.56	231.68	0.02	436.13	0.015
	Boro	5.00	1142.86	1347.30	204.44	0.01		

BCR: Benefit cost ratio.

Block farming of Rabi crops during 2012-13:

In the Rabi season of 2012-13, crops were cultivated according to the scheduled pattern. Required seeds and inputs were supplied to the farmers in time. Irrigation, weeding, and other practices were managed by the farmers. Block farming results of Rabi crops at different locations of the project site are shown in Table 2. High yielding varieties of each crop were used, such as BARI gom-26 for wheat, Binasloa-4 for chickpea, and Binasarisha-4 for mustard.

Results revealed that mustard (Binasarisha-4) produced seed yields of 1.50 to 1.80 t ha^{-1} with an average yield of 1.65 t $ha^{-1}$and maturity duration of 84 days (Table 2). A majority of farmers cultivated wheat (var. BARI gom-26) that produced seed yields of 3.30 to 4.20 t ha^{-1} with an average seed yield of 3.81 t ha^{-1}. Maturity duration of wheat was recorded as 123 days. Some of the farmers cultivated chickpea (Binasola-4) that produced an average yield of 1.46 t ha^{-1} and matured in 119 days.

Block farming of kharif-1 crops performed during 2012-13:

After Rabi crops, the same fields were used for kharif-1 crops, mungbean, and sesame. Seeds of Binamoog-5, Binamoog-8, Binatil-1 and Binatil-2 were supplied to the farmers as per plan. Required inputs (fertilizers) were also provided to the farmers for timely cultivating the following kharif-1 crops. During sowing time, soil moisture was very low. For this reason, a 3 cm post-sowing irrigation water was applied for the germination of seeds of the crops. Results of kharif-1 crops at various locations of the project site are shown in Table 3. The results indicated that average seed yield of mungbean (Binamoog-8) and sesame (Binatil-1) were 0.93 t ha^{-1} and 0.84 t ha^{-1}, respectively (Table 3). It was also observed that mungbean and sesame lack of water as they needed post-sowing irrigation and light supplemental irrigation during the pre-flowering stage. Moreover, mungbean and sesame were harvested by the end of June or the1st week of July, which was a suitable time for the kharif-2 crop, T. *aman* rice.

Pattern-based financial analysis of year-round cropping pattern demonstrated during 2012-13:

Year-round cropping pattern-based financial analysis for 2012-13 is shown in Table 4. It revealed that a maximum net income of $ 734.83 was obtained in the pattern No. V (Binadhan-7—Mustard—Sesame) with BCR of 0.017. The second highest BCR was obtained in pattern No. II with a net income of $ 643.82 and BCR 0.017. The rank orders of other patterns, in ascending order of importance, were No. VI, III, IV and I, while the economic return of the control was the lowest with a net income and BCR of $ 436.13and 0.015, respectively (Table 4).

This method of crop cultivation is very promising for increased crop production, improving farmers' socio-economic condition having sustainable water balance as well. Hence, the up-scaling of this project's findings is on-going to disseminate and popularize this cropping pattern in other areas through large scale block demonstrations, farmer trainings, field days, mass media campaigns, distribution of leaflets, etc. These up-scaling activities were also implemented through in front of pattern-based adaptation trials following participatory rural appraisal (PRA). The above evidence-based adaptation and up-scaling endeavors, following a needs-based participatory approach, are proven to be more effective in an extension system. Extension agents may follow this approach across the country for sustainable agriculture and food security

CONCLUSION

Recent studies on climate change have indicated that the global warming will continue in centuries ahead even if emission of greenhouse gases stabilize by maintaining 2000 levels (IPCC, 2007). Agricultural extension, in a bid to improve food production and overall standard of living of rural people, must face serious problems in the face of climate change. Necessary measures, such as development of resilient agro-technologies and its promotional activities, are imperative for agricultural extension to achieve its objective to combat the risk and vulnerability related to increased agricultural production and food security for the growing population of the country. Extension agents need to be well groomed in issues of climate change and adaptation strategies relevant to the farmer's need. Extension agents need to be trained to develop their understanding of the causes of climate change and managing local resilience in their own field. They should also minimize vulnerabilities in their agricultural system. The government needs to develop and follow appropriate policies to back-up institutional efforts to combat the threats of climate change in agriculture. All these factors, amongst others, if neglected, will make a mirage of the efforts made by agricultural extension practitioners to bring about food security. The threat and risk posed by climate change will in no doubt affect the yield and overall productivity of the farmers.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

The review article has been successfully done with helping with others. Bir designed and performleed the experiments and also wrote the manuscript. RH, MH, and SI performed treatments, data collection, and data analysis. KO and KW designed experiments and reviewed the manuscript. All authors read and approved the final version.

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