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CLIMATE VARIABILITY AND HOMESTEAD PRODUCTION RESOURCES IN CENTRAL TERRACE ECOSYSTEM OF BANGLADESH

M. Ahmed[1], M. A. Rahman[1], M. G. Miah[1] and A. M. Akanda[2]

[1]Dept. of Agroforestry and Environment and [2]Dept. of Plant Pathology
Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU)
Gazipur-1706, Bangladesh

Abstract

A study was conducted to examine the impact of climate variability on homestead production system in the central terrace ecosystem of Bangladesh. The study was conducted through household survey by interviewing 90 farm households.Analyses of climatic parameters indicate that rainfall during monsoon has increased by 8.6 %, while it decreased by 19.4 % in dry season in last 10 years. Both maximum and minimum temperatures showed increasing trend. Changing in climatic parameters, adversely affected the homestead production systems in central terrace ecosystem. A total of 42 tree species and 29 vegetable species were identified in the studied homesteads, among them *Tamarindus indica*, *Punica granatum*, *Annona squamosa*, *Bombax ceiba*were reported to be endangered tree species in different degrees. During the last ten years, planting of *Citrus reticulata* has been increased due to its acid tolerant capability and high income, while*Tamarindus indica*, *Aegle marmelos*, *Annona squamosa*, *Phoenix sylvestris*, *Manilkara achras* were decreased. Among the forest species, *Swietenia macrophylla* and *Acacia auriculiformis* were found increased; while *Gmelina arborea*, *Lagerstroemia speciosa*, *Albizia sp* were decreased compared to past decade. The production of livestock feed and fodder declined drastically, which eventually reduced livestock population.

Keywords: Climate variability, homestead, production system, tree species.

Introduction

Climate change is a burning issue for the whole world, especially low-lying and developing countries. Bangladesh is recognized as one of the most vulnerable countries in view of impacts of global warming and climate change. This is due to her unique geographic location, dominance of floodplains, low elevation from the sea, high population density and high level of poverty (IUCN, 2009).The impact of climate change on the frequency of tropical storm is uncertain, but the sea-surface temperature over the North Indian Ocean has been warmed by about 0.6°C since 1960 and warmer ocean waters are expected to lead increasing the intensity of tropical storm (IPCC, 2007). The climate change events significantly hinder the agriculture production systems, economic and social development of the country by means of damaging crops, livestock, fisheries and forestry. Changing climate is creating adverse impacts on agriculture and ecology in different parts of Bangladesh, especially in coastal, drought and terrace ecosystem (FAO, 2003).

Central terrace ecosystem is an important region comprising about eight percent of the total land mass of Bangladesh. It is a region of complex relief and soil developed over the Madhupur Clay. This is a transitory zone among the south-eastern, north-western and south-western zones. In this region, rainfall is abundant (1,900 mm) and the production systems particularly in homesteads are well developed as this zone is almost free from flood (Anon., 2006).

Homestead agroforestry is an age old practice and an integral part of the traditional farming system in this region like other parts of Bangladesh. In the homestead, various crops, trees, animals, livestock and fishery are grown in mixture. Homesteads are more reliable than crop land as production unit. Because homestead is less vulnerable to flood as well as other natural hazards. It is also more stable than crop fields from socio-economic standpoint as farmers never sell their homesteads before their crop land. Homesteads play an important role in the economy of Bangladesh and provide nearly 50 % cash flow to the rural poor (Miah and Hussain 2010).

Now-a-days, it is found that homestead productivity is decreasing because it is now highly vulnerable to climate change like drought, high humidity and other causes (Anon., 2006). Local communities have been trying to cope up with the changing scenarios with various adaptation programs based on experiences and available knowledge. Having understanding the importance of climate change issues, it is needed to identify the extent of climatic variability of this region. It is also needed to know about how the farming communities are taking adoption steps with this changing scenario and what would be the best option to cope up with this situation? All the aforesaid information will be useful to develop policies and programs under the changing scenario for environmentally compatible and economically viable production/livelihood systems. Taking these factors into consideration, a typical site of the Central Terrace Ecosystem was selected with the aim for assessing the climate variability and changing pattern of homestead production systems in central terrace ecosystem of Bangladesh.

Materials and Method

The study was conducted in three villages namely Barjuna, Nakasini and Korolia under Kapasia Upazila of Gazipur District. The long term meteorological data (1961-2010) were collected from the nearby Meteorology Station and then analyzed to identify the climate variability and extreme events and to verify the climate variability and events with the farmer experiences and perceptions.

Climatic parameters were analyzed by calculating LCL (Lower Confidence Level) and UCL (Upper Confidence Level) from the period of 1960-2000.

LCL= X -2.025 * {SD (1960-2000)/ SQ (n)}

UCL= X +2.025 * {SD (1960-2000)/ SQ (n)}

Here

X= Average of 1960-2000 observation

SD= Standard deviation of 1960-2000 observation

SQ= Square root of 1960-2000 observation,

n= Number of observation

2.025= Coefficient factor

Ninety respondents from three villages were extensively interviewed through pre-tested questionnaire during November 2010 to February 2011. Focal Group Discussions (FDGs) were made to verify the information and to know the important issues. The major parameters which were included in the study were socio-economic, changing pattern of homestead production systems, perception of climate change and its impacts. The changing patternof homestead production systems of the respondents on climate change were compared to current time to at least 10 years back. Major adaptation measures are being undertaken by the local community and possible steps to be undertaken to sustain the homestead farming were also studied. To indicate the importance and species richness of different plant species in study area, Relative Prevalence (RP) of species was calculated as follows:

RP = Population of the species per homestead * percent homesteads with the species.

The Shannon-Wiener Index (SWI) was also used to evaluate the species richness and abundance of trees in all three locations (Margurran, 1988). The proportion of species (i) relative to the total number of species (pi) was calculated and then multiplied by the natural logarithm of the same proportion (lnpi). The resulting product is summed across species, and multiplied by -1.

$$SWI = p_i[\ln(p_i)]$$

The Standardized Precipitation Index (SPI) calculation for any location is based on the long-term precipitation records for a desired time period. This long-term record is fitted to probability distribution, which is then transformed into a normal distribution (Edwards and McKee, 1997). It reflects the number of standard deviations that an observed value deviates from the long-term mean.

$$SPI = \frac{Xi - X}{\sigma}$$

Where, SPI is Standardized Precipitation Index $X\,i$ - X; and ? are ith year precipitation, long term mean of precipitation and standard deviation of mean, respectively.

After collection of data, all information contained in the interview schedule were edited. Statistical Package of Social Science (SPSS) computer software was used to analyze the data. Statistical measures, such as frequency counts, percentages, range, mean and standard deviation were used to describe the data.

Results and Discussion

Climate Variability

Analyses of long term weather data (1960 to 2009) showed that the climate has been changing remarkably since last 10 years. It was observed that the highest and lowest minimum temperatures were 25.84 and 11.81°C, respectively, during the period of 1960 to 2000, while the upper and lower limits of temperatures were 26.05 and 11.78°C respectively, in the period of 2001 to 2008. Data indicates that the highest minimum temperature was increased by 0.21°C in recent years, while the lowest minimum temperature was remained almost unchanged (Figure 1). Similarly, maximum temperature was slightly increased during the summer season and decreased during the winter season (Figure 2).

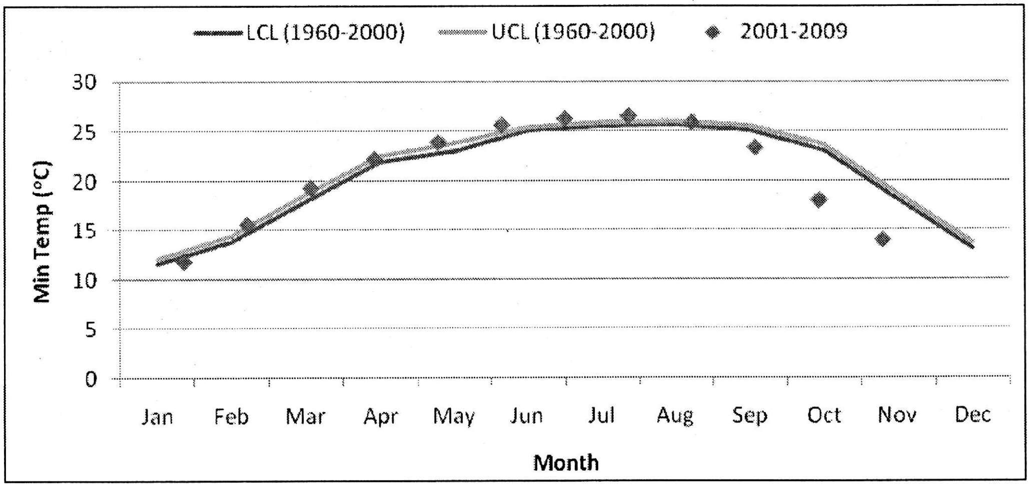

Figure 1. Changes in average monthly minimum temperature in the study area during 2001-2009 (LCL= Lower Confidence Level, UCL= Upper Confidence Level).

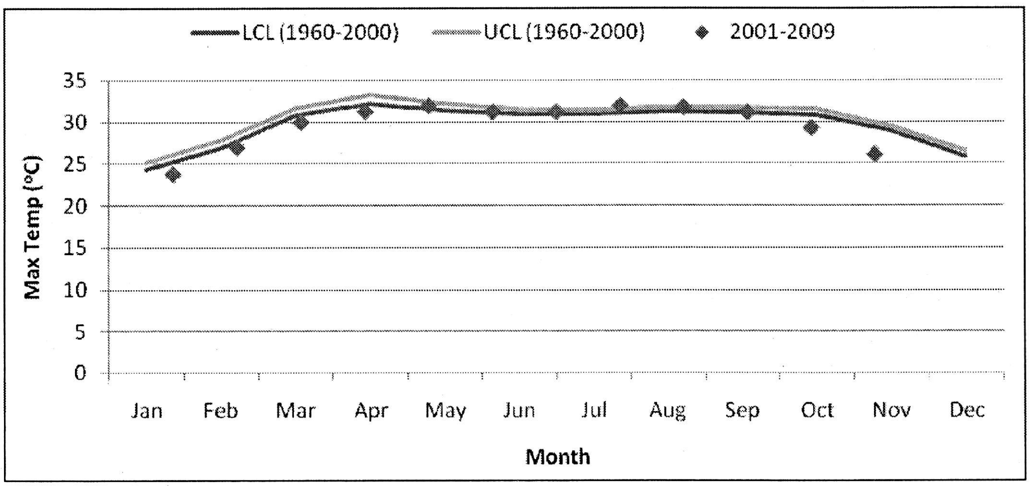

Figure 2. Changes in average monthly maximum temperature in the study area during 2001-2009 (LCL= Lower Confidence Level, UCL= Upper Confidence Level).

Distribution of monthly rainfall also showed remarkable change. Rainfall during dry season (November through March) decreased by 9.4 mm, while average rainfall during monsoon (June through August) increased by 122.96 mm during 2001-2009 (Figure 3). On the other hand, relative humidity showed an increasing trend in recent years (2001-2009 period) compared to that of previous years (1960-2000 period) (Figure 4).

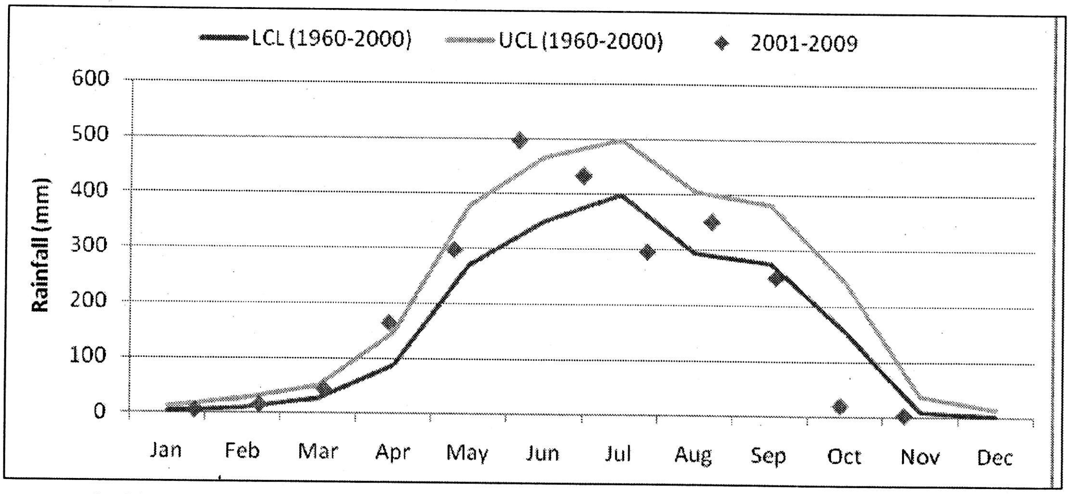

Figure 3. Changes in average monthly rainfall in the study area during 2001-2009 (LCL= Lower Confidence Level, UCL= Upper Confidence Level).

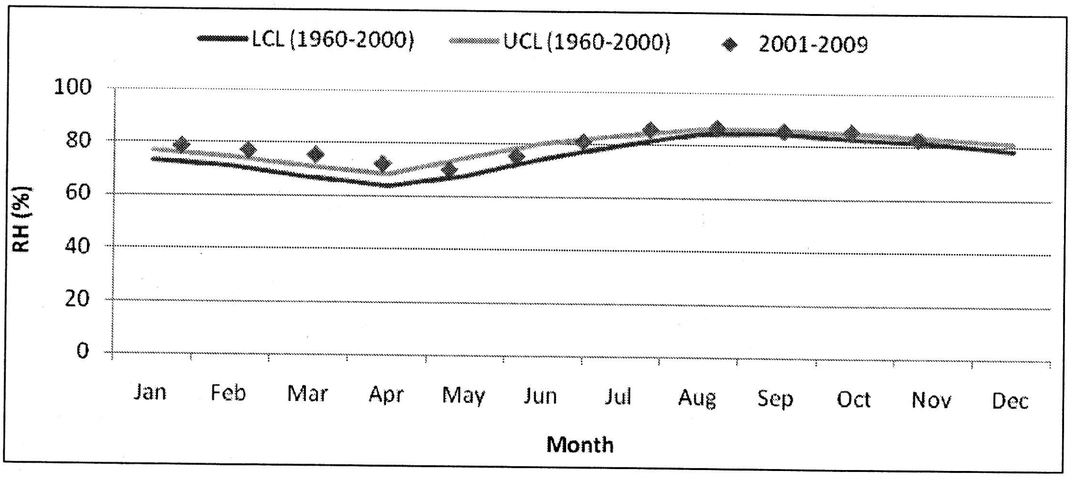

Figure 4. Changes in average monthly relative humidity in the study area during 2001-2009 (LCL= Lower Confidence Level, UCL= Upper Confidence Level).

Decadal change of climate

Analyses of decadal weather data showed that climate had also been changed in the last decade. It was observed that the highest maximum temperature (33.25°C) was found in 1971-80 decade in the month of April-May followed by 1961-70 (33.24°C), 1991-2000 (32.18°C), 1981-90 (31.91°C) and 2001-09 (31.25°C). As a result severe drought was recorded in

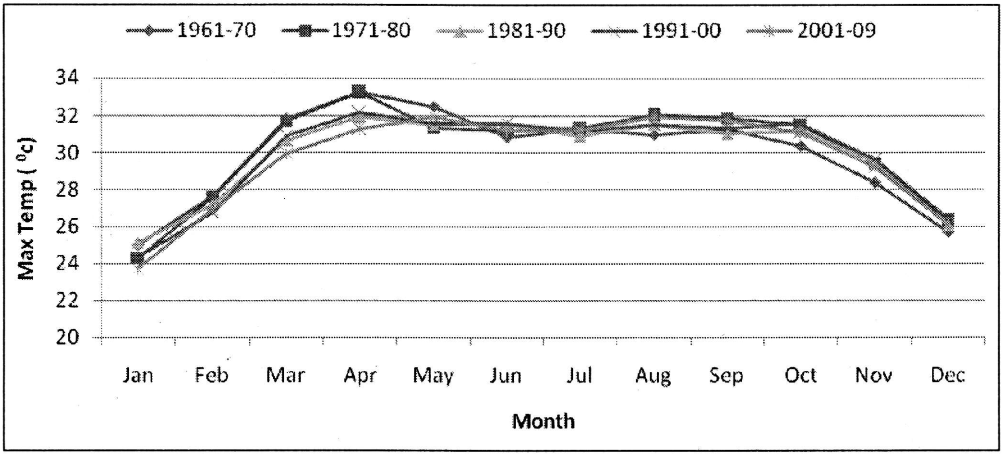

Figure 5. Changes in decadal monthly maximum temperature in the study area during 1961-2009.

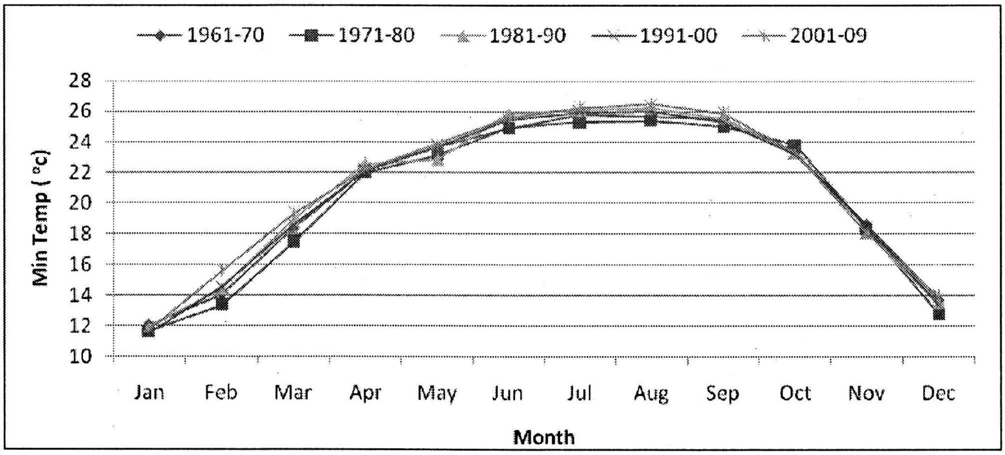

Figure 6. Changes in decadal monthly minimum temperature in the study area during 1961-2009.

1971-80 decade (Anon., 2008). On the other hand, the lowest maximum temperature (23.75°C) was found in 2001-09 followed by 1991-2000 (24.33°C), 1961-70 (24.97°C), 1971-80 (24.27°C) and 1981-90 (25.13°C) in the month of January (Figure 5). In case of minimum temperature, 2001-09 decade showed the maximum (26.50°C) followed by 1981-90 (26.22°C), 1991-2000 (26.03°C), 1961-70 (25.69°C) and 1971-80 (25.39°C) (Figure6).

Distribution of monthly rainfall graph showed an amazing change in the studied period. Among the months, the highest rainfall 550.90 mm was recorded in 1981-1990 followed by 2001-09 (433.38 mm), 1961-70 (429.90 mm), 1991-2000 (424.3 mm) and 1971-80 (398.5 mm) in the month of July. On the other hand, 2001-09 decade showed the maximum change of rainfall followed by others in rest of the month (Figure 7). The highest and lowest rainfalls were recorded in June-July and Nov-Dec month, respectively, in most of the cases. On the other hand, relative humidity showed an increasing trend, which was maximum in 2001-09 (86.55 %) decade in the month of September followed by 1981-90 (86.2 %), and 1991-2000 (84.6 %) decade; and the lowest (61.3 %) one was recorded in 1991-2000 decade followed by 1981-90 (68.1 %), 2001-09 (69.88 %), 1971-80 (74.0 %) decades (Figure 8). It showed that 2001-2009 and 1981-1990 decades experienced extreme natural disasters (Anon., 2008).

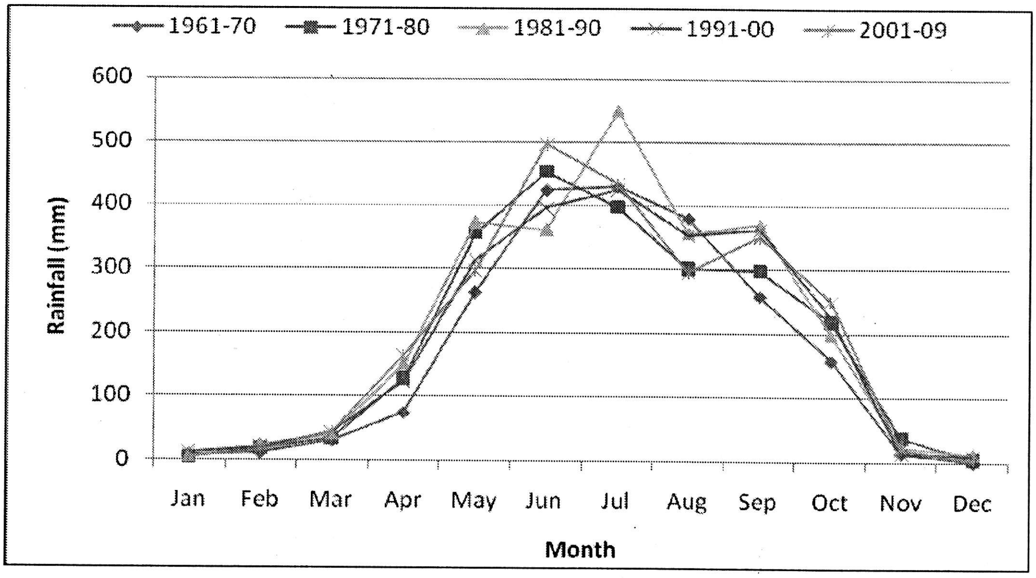

Figure 7. Changes in decadal monthly rainfall in the study area during 1961-2009.

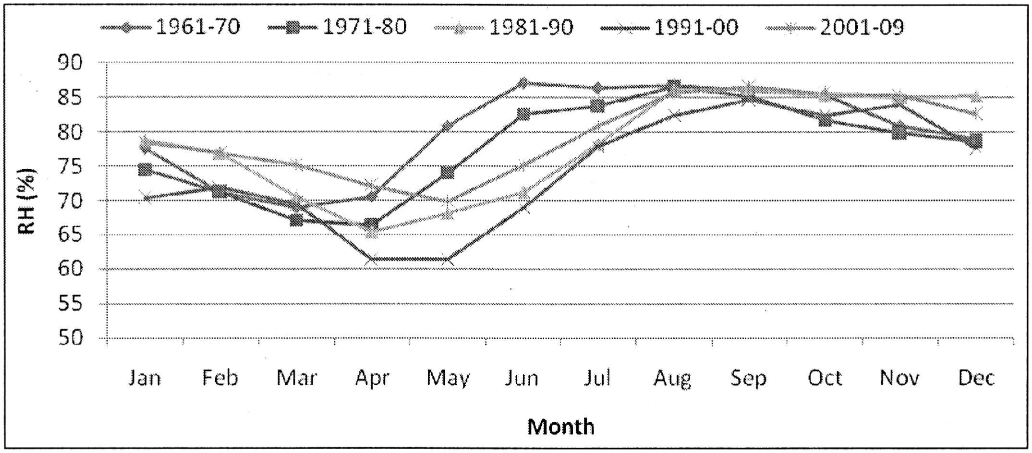

Figure 8. Changes in decadal monthly relative humidity in the study area during 1961-2009.

Frequency of SPI corresponding drought and wet condition

The annual drought and wet frequency corresponding to SPI (Standardized Precipitation Index) in the study area has been shown in Figure 9. The result revealed that drought frequency was dominant in the recent years and the SPI values crossed the normal level (-0.5 to +0.5) in most of the years. Subash and Mohan (2011) reported wide year-to-year variation in the monthly distribution of rainfall in Indo-Gangetic region.

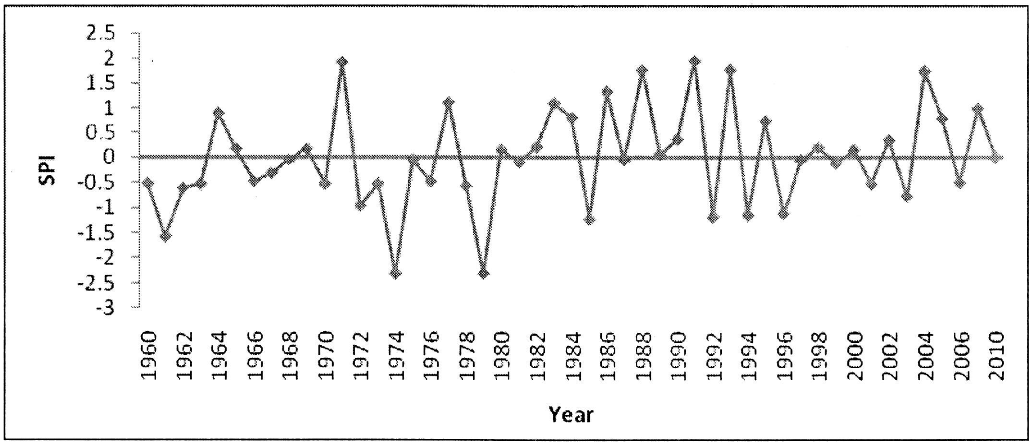

Figure 9. Long-term (1960-2009) annual Standardized Precipitation Index (SPI) in the study area indicating frequency of dry and wet conditions.

Increase in monsoon rainfall was thought to be responsible for flash flood resulting damage of vegetation, while decrease in winter rainfall might result prolong drought which consequently might occur stunted growth of vegetation and create obstruction in sowing winter crops. Moreover, seasonal variation in weather parameters might have also increased the disease, insect and pest incidences intrees and crops as well as the other vegetations. A warmer climate with uncertain winter rainfall is likely to affect not only agricultural crops or forests but also other sectors like health, water etc.The monsoon rainfall increased by 56.4 mm in recent decade compared to base decade, while it was decreased by 1.17 mm during dry season. Decreasing trend of winter season rainfall is associated with higher rate of increase in minimum temperature (Wang et al. 2009) that might had hampered the growth of the vegetation.

Opinion of farmers on climate change

Respondent's experiences in terms of climate change are shown in Table1. It was observed that climate had been changing gradually. The respondents' opined changing pattern on rainy period (76.92%), day temp (84.61 %), night temp (84.61 %), drought reached to a high level followed by amount of rainfall (7.69 %), mist (7.69 %), dew (7.69 %), fog (15.38 %) and storm (7.69 %). These events were likely to result in increase vulnerability to cyclone and storm surges, prolong drought, salinity intrusion, which were in good agreement with Schneider (1989).

Table 1. Respondents opinion about climate change scenario during past 10 years in the study area

Observation	Percent Respondents									
	Amount rainfall	Rainy period	Day Temp	Night Temp	Mist	Dew	Fog	Flood	Drought	Storm
High	7.69	76.92	84.61	84.61	7.69	7.69	15.38	-	84.61	7.69
Low	61.53	15.38	-	-	76.92	76.92	76.92	92.3	-	76.92
Fluctuate	30.76	-	15.38	15.38	15.38	15.38	-	7.69	15.38	15.38
No Change	-	7.69	-	-	-	-	7.69	-	-	-
No Idea	-	-	-	-	-	-	-	-	-	-
Total	100	100	100	100	100	100	100	100	100	100

Homestead Production System

Land resource

Changing scenario in utilization of land resources compared to 10 years ago is presented in Table 2. At present, the maximum land (166.07 decimal) was utilized as crop land followed by homestead (12.5 de), pond (5.65 de), housing (4.10 de) and vegetable plot (2.11 de). The present land use pattern compared to 10 years ago showed remarkable decreasing trends for all sector except housing. About 9.33% more lands were used for housing compared to 10 years ago. This may be due to increase of population. The land areas for vegetable field, pond, crop land and homestead were decreased by 59.81, 46.19, 37.68 and 18.57% compared to 10 years ago. Surprisingly 98.87% fallow land was decreased, which was brought under crop cultivation and other usage. Recently due to high population pressure and lower crop productivity farmer used to utilize the fallow land for crop production.

Table 2. Changing scenario in utilization of land resources compared to 10 years ago in thestudy area

Land use	Farm size (Decimal)	Change	
	At Present	10 years ago	(Percent)
Housing	4.10	3.75	+9.33
Homestead	12.50	15.35	-18.57
Crop land	166.07	266.5	-37.68
Vegetable field	2.11	5.25	-59.81
Pond	5.65	10.5	-46.19
Fallow land	0.066	5.85	-98.87

Tree species in the homestead

Species richness

Number of trees (both fruit and timber species) was changed over time in the studied homesteads (Table 3). Ten years ago, timber species was most dominant (12.13 per farm) followed by fruit species (11.03 per farm) and vegetable species (8.79 per farm). At present, although the trend of species composition is similar, but all species showed decrease in number. Currently 39.29% decreasing trend has been found for fruit tree species followed by timber species. Recently growing of timber species is profitable which leads the farmer to grow more timber species. The finding is in good agreement with the finding of Mannan (2000).

Table 3. Changing scenario on the abundance of tree species compared to 10 years ago inthe study area

Category	Number/Farm		Change
	At present	10 years ago	(percent)
Fruit species	6.64	11.03	-39.29
Timber species	7.48	12.13	-36.97
Vegetable species	6.19	8.79	-29.51

Relative prevalence of tree species

Relative prevalence (RP) of different timber, fruit, medicinal and ornamental species (excluded banana, bamboo and other trees inconvenient to count) is shown in the Table 4. A total of 42 tree species was identified in the surveyed homesteads. The most prevalent and top ranked forest species were *Swietenia macrophylla*, *Acacia auriculiformis*, *Albizia* sp and *Shorea robusta*; while *Mangifera indica*, *Artocarpus heterophyllus*, *Cocos nucifera*, *Areca catechu* and *Litchi sinensis* were most prevailed fruit species and *Azadirachta indica* was as medicinal species. The variation in number of different species at the homesteads was wide, which indicated high plant biodiversity. Many species were very poor in number that indicated diminishing trend of homestead plant diversity. Once homesteads in central ecosystem were considered as rich in species, but currently it can be easily understood that a lot of local and indigenous species have been either extinct or at endangered level due to climate change and anthropogenic activities.

In general, the relative prevalence of different tree species was considered as indicator of species dominance. Relative prevalence of most of the fruit species decreased compared to ten years back, except orange. During the last ten years, planting of orange had been increasing due to its good acid tolerant capability and high market price. Among the fruit species, the minimum relative prevalence was observed in *Tamarindus indica* indicating most affected species in homestead. Lower relative prevalence was also found in *Aegle marmelos*, *Annona squamosa*, *Phoenix sylvestris*, *Carissa carandas*, *Manilkara achras*, *Bixa orellana*, *Zizyphus jujuba* etc. Among the forest species, the relative prevalence was increased in *Swietenia macrophylla* and *Acacia auriculiformis*. On the other hand, relative prevalence was found decreased in *Gmelina arborea*, *Borassus flabellifer*, *Lagerstroemia speciosa*, *Artocarpus chapalasha*, *Eucalyptus camaldulensis*, *Albizia* sp etc compared to last ten years period.

Table 4. Changing scenario on the relative prevalence of tree species compared to 10 yearsago in the study area

Name of the fruit tree species	Relative prevalence of fruit trees		
	At Present	**10 years ago**	**Change (percent)**
Mangifera indica	6.40	8.73	-36.41
Litchi chinensis	3.40	5.55	-63.24
Cocos nucifera	4.66	4.95	-6.22
Artocarpus heterophyllus	5.55	8.4	-51.35
Zizyphus jujuba	0.81	1.89	-133.33
Aegle marmelos	0.14	0.95	-578.57
Areca catechu	3.74	9.23	-146.79
Phoenix sylvestris	0.91	3.55	-290.11
Bixa orellana	0.26	0.78	-200.00
Manilkara achras	0.09	0.35	-288.89
Tamarindus indica	0.02	0.35	-1650.00
Annona squamosa	0.20	0.98	-390.00
Carissa carandas	0.15	0.55	-266.67
Citrus aurantum	0.13	0	+100.00
Name of the timber species	**Changes of relative prevalence of timber species**		
	At Present	**10 years ago**	**Change (percent)**
Swietenia macrophylla	4.76	1.12	+76.47
Tectona grandis	0.29	1.25	-331.03
Acacia auriculiformis	2.07	1.12	+45.89
Albizia sp.	1.15	3.55	-208.70
Eucalyptus camaldulensis	0.14	0.45	-221.43
Artocarpus chapalasha	0.03	0.12	-300.00
Lagerstroemia speciosa	0.01	0.05	-400.00
Gmelina arborea	0.23	1.25	-443.48
Borassus flabellifer	0.43	2.21	-413.95
Shorea robusta	0.61	1.14	-86.89
Azadirachta indica	0.13	1.08	-730.77

Shannon-Weiner Index (SWI)

A remarkable variation was found in species diversity at homestead as indicated by SWI among three villages (Figure 10). Analysis of variance indicated a significant difference between the diversity expressed by the SWI in home gardens of the three sites.Home gardens in *Barjuna consisted* with comparatively higher species, generic and family diversity of tree species (2.98) than other two villages. Home gardens studied in Korolia had the lowest level of diversity of tree species (0.94). This is also reported by Marambe *et al.* 2012 in the same region.

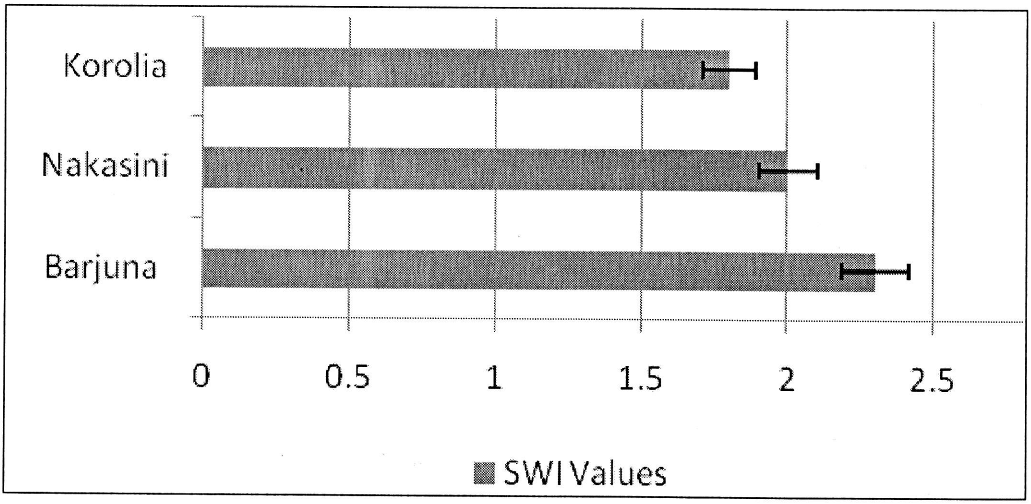

Figure 10. Average of SWI of home gardens in the study area.

Livestock and poultry population

Livestock is an indispensable component of farming systems practiced by landless, marginal and small farmers especially in the homesteads. Rearing livestock and poultry in the backyard of a homestead was found as a major source of income and it was found to support the livelihood activities of a large number of farmers, particularly landless, marginal and small farmers. Increase of cultivable land and urbanization had reduced the availability of grazing lands and fodder, which made livestock difficult to survive and exist.

The survey result showed a sharp decline in the productivity of livestock and poultry in the study area (Table 5). At present, all the livestock and poultry population showed decreasing trend compared to 10 years ago. It was observed that buffalo population was decreased cent percent followed by sheep (97.40 %), goat (87.67 %), pigeon (79.72 %), poultry (66.95 %), cattle (64.23 %) and duck (55.53 %) in the study area as compared to last ten years back. The findings are in good agreement with Miah *et al.* (1990).

Table 5. Changing scenario of livestock population compared to 10 years ago in the studyarea

Category	Number/Farm		Change
	At present	10 years ago	(percent)
Cattle	1.86	5.20	-64.23
Buffalo	0	2	-100.00
Goat	0.74	6	-87.67
Sheep	0.1	3.85	-97.40
Poultry	6.65	20.12	-66.95
Duck	1.93	4.34	-55.53
Pigeon	2.88	14.20	-79.72

Decline in the livestock population had resulted many management problems for agricultural production. Firstly, it resulted in the shortage of draft power for ploughing, traction power and transportation, impeding cultivation and post harvest processing and marketing. Secondly, decreased the quality of dairy goods resulted the shortage of baby food as well as components of other nutritional diet for children and adults. Thirdly, women's traditional roles of collecting dung for fuel has been gradually diminishing as cattle were disappeared (Adnan, 1993). Similarly, the production of meat and milk has decreased due to decrease of livestock and poultry population. But it was also reported that ducks were also decreased due to reduction of water bodies such as 'beel' and dryness of the ponds in homestead area as a result of climate change and human activities.

Endangered tree species

Homestead is a traditional agroforestry system where various types of plants grow in mixture. Farmers opined that many tree species were at endangered, nearly extinct and extinct levelsin the study area due to poor productivity and unknown reasons. Table 8 indicated that tamarind was the mostly affected and almost extinct level followed by pomegranate, custard apple, silk cotton and fig.

Table8. Endangered trees in homestead in the study area

Plant species	Endangered tree species	
	Respondent	Percentage
Tamarind (*Tamarindus indica*)	67	28.51
Pomegranate (*Punica gratum*)	55	23.40
Custard apple (*Annona squamosa*)	45	19.15
Silk cotton (*Bombax ceiba*)	25	10.64
Fig (*Ficus carica*)	22	9.36
Velvet apple (*Diospuros discolor*)	21	8.93

Conclusion

The study revealed that status of local community was medium resource base and currently they are heavily dependent on the homestead resources for their livelihoods. Increasing trend of climate change particularly temperature and rainfall and anthropogenic activities are the reasons for decreasing the natural resources in homestead. Analyses of climatic parameters showed that temperature and relative humidity increased over time might have favored spreading of diseases and insect infestations and ultimately hampered production system. Similarly, the monsoon rainfall was increased by 122.96 mm and dry season rainfall decreased by 9.4 mm compared to the past 30 years back that made agricultural as well as homestead production systems difficult in central terrace ecosystem of Bangladesh. As a result, all types of species were decreased in homestead due to climate change. However, the worst affected and most prevalent non-forest species in central terrace ecosystem were *Swietenia macrophylla*, *Acacia auriculiformis* and *Albizia* sp.; while the fruit species were *Mangifera indica*, *Artocarpus heterophyllus*, *Cocos nucifera*, *Areca catechu*, and *Litchi sinensis*; and medicinal species were *Azadirachta indica*. Not only plant species but also animal species were mostly affected due to climate variability.

The community people have taken some adaptation measures like changing planting time, using new technologies etc. However, community strongly opined that the concerned authorities should take appropriate measures like construction of water reservoirs, deep tube well through community approach/partnership, development of pest and disease resistant variety etc. These might have positive benefits to combat the impacts of climate change and anthropogenic activities to a considerable extent and creating their better livelihood opportunities.

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