Agroforestry Ecological Zone Modeling Guidelines For Hill Regions

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***Abstract*– Agro-ecology believed to provide the opportunities to circumvent the two disciplines – agronomy, forestry and in place of monoculture shift to polycultural system which tends to lead to the natural ecosystem. In large agroecological entity agriculture, forestry and agroforestry are treated not as separate disciplines. The agroecological zones (AEZ) of Bangladesh are classified primarily on the basis of land type, soil characteristics, soil-water regime and agro-climatic factors. From the dawn of civilization, sustainable food security has been a major human goal.**

***Keywords*— Integrated forestry; modeling; agro-ecology; zoning**

I. INTRODUCTION

Modern agriculture and forestry, without an agroecological perspective, has gone a long way toward satisfying the demand for food, fiber and other products. Most of the current productive potential is centered on monoculture systems and, with these comes some associated environmental problems.

Given that the infrastructure and in-field knowledge base is fixed, the obvious direction toward increased productivity is through chemical applications and genetic modifications. Although not a complete substitute, agroecology offers alternatives. Agroecology offers alternatives that are difficult to achieve with a traditional approach. A polyculture in agriculture or forestry can provide increased per area outputs, lower associated costs, and/or reduce climatic and market risk. The added complexity and the advantages inherent in a biodiverse plot or landscape may be better approached using agroecological principles.

Agroecology can be defined as the study and application of ecological principles to planned and managed ecosystems in order to achieve socio-economic, environmental, and/ or cultural objectives. This is a very broad view of agroecology, one that encompasses productive systems of agronomy, forestry and agroforestry. A number of concept underline and traditional disciplines are encompassed by agroecology. The full extent of this is demonstrated by the agroecological triangle. The agroecological triangle (fig.1) helps put agroecology in perspective. In this, agriculture, forestry and agroforestry are not separate disciplines, but are part of the larger agroecological entity.

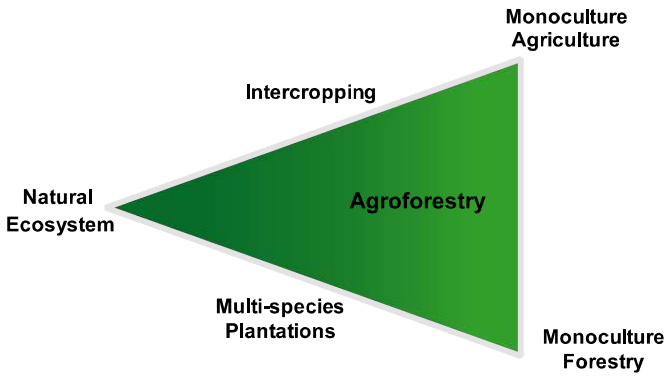

Fig. 1: The Agro Ecological Triangle showing the relationship between agronomy, forestry and agro forestry (P. A. Wajikowski. 2002)

The right extent of the triangle represents monoculture agriculture and forestry. The upper right apex depicts short-duration agriculture monocultures and the lower right apex longer duration forestry monocultures. The left apex represents the unaltered natural ecosystem.

Going from right to left within the triangle are agroecosystems of greater biodiversity and more complexity. This is demonstrated along the top boundary where the monocultural apex gives way to inter cropping. A similar progression exists along the lower forestry boundary. In comparison to monoculture of forestry plantations, multi-species plantations have more planned biodiversity. Still more biodiverse are those silvicultural prescriptions that remove the less valuable species from forests. This progression ends with the species, spatial and temporal complexity of the natural ecosystem.

Within the triangle are various mixes of crops and trees, offering a vast array of polycultural systems that contribute to agroecology. A large percentage of the available, but often less used options, is those employing trees in close association with crops.

Agroforestry refers to the deliberate introduction or retention of trees on farms to increase, diversify and sustain production for increased social, economic and environmental benefits. Agroforestry system classification can be based on vegetation structure, function of woody perennials in the system, levels of management input and environmental conditions and ecological suitability of the system.

Several definitions have been proposed to agroforestry, of which the most commonly used are those of Lundgreen and Raintree (1982) and Leakey (1996). Agroforestry is any land-use system, practice or technology where woody perennials are integrated with agricultural crops and or animals in the same land management unit, in some form of spatial arrangement or temporal sequence. Agroforestry is also a dynamic and ecologically based natural resource management system.

Agroecological zone-land areas recognized on the basis a hydrology, physiographic, soil type, tidal activity, cropping patterns and seasons. In fact an agroecological zone indicates an area characterized by homogenous agricultural and ecological characteristics. This homogeneity is more prominent in the sub region and unit levels. The agroecological zones of Bangladesh have been identified on the basis of four elements, such as physiographic, soils, land levels in relation to flooding and agroclimatology. Bangladesh has been divided into 30 agroecological zones. These 30 zones have been sub divided into 88 agroecological sub regions, which have been further sub divided into 535 agroecological units. In 2002 IUCN Bangladesh, highlighting the biological and ecological attributes of the country zoning of land was done. In this regard 25 bio-ecological zones were constituted some of which are comprised of one or more than one type of ecosystems i.e. land based and aquatic ecosystems.

Objectives

1. To identify the Agro-forestry species as per Agro-Ecological Regions of Bangladesh.
2. To assess agroforestry parameters as per productivity potential of Hill regions of Bangladesh.
3. To prioritize the guideline points of the model of the AFEZs of Bangladesh.

II. LITERATURE REVIEW

The growing of trees in homegardens is a traditional practice throughout Southeast Asia. It is referred to as the oldest land use activity next to shifting cultivation (Kumar and Nair, 2004, 2006), with the earliest evidence of garden cultivation dating back to 7000–3000 BC (Soemarwoto, 1987) or even to 13,000–9,000 (Wiersum, 2006). Homegardens can be classified on the basis of a variety of functions and services, for example gardens for pure survival (survival gardens), subsistence (subsistence gardens), market production (market gardens), hobby (household budget gardens), communal medicine production (village herbal or medicinal garden) or various ecological gardens (bio-gardens) (Wiersum, 2006). There is a growing awareness that homegardening, combined with nutritional education, can be a viable strategy for improving household food security and optimize nutritional diversity for at-risk populations, particularly women and children (Kumar and Nair, 2004).

In Bangladesh there is a long tradition of tree growing in homesteads and homegardens like elsewhere in Southeast Asia (Ahmed and Ali, 2003). Likewise tree growing in the form of traditional forestry has been practiced in the form of village forests, tea and rubber gardens and shifting cultivation systems in hill forests (Islam, 2013). Whereas in present times homegardens cover only about 2.3 percent of the land (Jensen, 1995), village forests play a more important role supplying 80 to 82 percent of the forests products in villages (Forestry Master Plan, 1992). It is estimated that these forests cover about 270,000 ha (Forestry Master Plan, 1992) containing, amongst others, bamboo, palms, and trees for fruit, fuel wood, construction, shade, and other multiple purposes.

Trees can reduce the impacts of weather extremes such as droughts or torrential rain (Mutegi, et. el. 2008). Research has also demonstrated that the tree component of agroforestry sytems stabilize the soil against landslides and raise infiltration rates. This limits the surface flow during the raining season and increases groundwater release during the dry season (Ma, et. el. 2009).

Tree based systems have advantages for maintaining production during wetter and dry season. Trees improve soil quality and fertility by contributing to water retention and by reducing water stress during low rainfall years (Martin and Sherman, 1992).

Agroforestry is the most effective land use system from the sustainable point of view and is recognized worldwide as the best productive system from which the rural poor people can meet their requirement of food, fuel, fodder and other necessities. This has long been practiced by the farmers of Bangladesh in casual manner. The homestead of rural people is unique feature of combination of trees, shrubs, vegetable, livestock animals, and duck and poultry birds in association with trees of different multipurpose values. Estimated 16.7 million homestead of the country occupy about 0.3 million hectare of land (which is increasing sharply with the increase of population) in now under traditional agroforestry practices. There is a great scope to manage and develop these homesteads with sound sustainable technologies. Because the homesteads are providing the lion share of bio-fuel requirement as well as fruit, fodder, timber and shelter for rural people. Besides the homestead, part of our cropper land (net cropper area is 8085 m ha), 0.39 m ha current fallow land, 0.27 m ha culturable waste land, 3.29 m ha land which is not available for cultivation and encroached forests areas in Madhupur Sal forests and other plain land forests in Dhaka, Gazipur, Tangail, Mymensing district, CHTs forests along with the denuded hills of greater Chittagong and Sylhet region may bring under agroforestry systems. Utilizing appropriate agroforestry technologies in these areas the overall production may be increased many folds (Hasanuzzaman, M. 2009).

III. METHODOLOGY

Methods of Data Collection

Methodology shows the approach by which the study is accomplished. It includes some sequential steps that are required for performing the study effectively. This study is

mainly based on primary and secondary data through which the study is completed.

Researcher conducted the face to face interview with the respondents of the study areas. As per the plan for data collection the researcher communicated the concerned officials by emails, telephone/ mobile phone for appointment with the respective respondents. The researcher took help of his colleagues and friends during conducting data collection. Data were collected from the capital and the field level conducting interview, discussion and observation using primary source i.e. interview with the respondents from the selected study areas. Primary data were collected through interview. Data were also collected from secondary source through literature review i.e. reference books, newspapers, periodicals, articles from concern journals of national and international level. Internet sources have been used for research. An attempt was made to include the latest informations whenever available.

Variables

The major variables used in the research include:

a. AEZ site districts and sub-districts
b. Hill Agroforestry species
c. AGF Hill interactions

Study Population: All 30 AEZ and General soil Types

Respondents

i. Forest Rangers
ii. Forest conservationists
iii. Forest Trainers
iv. agricultural Scientists
v. Primitive livelihood systems
vi. Development engineers
vii. Local Political Leaders
viii. Geographers
ix. Roads and Highway Engineers
x. Nature conservationists

Questionnaire

1. Technical Study Format: AEZ and AFEZ cluster analysis

AEZ: Major Locations

AEZ	AEZ name	AFEZ name	Major area Districts
1	Old Himal Piedmont	1 AFEZ Himatista	Panchagar, Thakugaon, Nilphamari, Rangpur, Lalmonirhat, Dinajpur
2	Active Tista FP		
3	Tista Meander FP		
4	Korotoa- Bang FP	2 AFEZ Koratrai	Sirajganj, Bogra Noagaon, Natore
5	Lower Atrai Basin		
6	Lower Purna FP		
7	Active Brahm-Jam FP	3 AFEZ Brahma	Kuri, Gai, Bogr, Pab, Sher, Manik, Jamal, Tangail, Dhaka, Munsi, Mym, Netrakona
8	Young Brah Jam FP		
9	Old Brahmaputra FP		
10	Active Ganges FP	4 AFEZ Ganges	Nowabganj, Rajsh, Jhenaida Natore, Pabna, GFaridpur, Kustia Khulna
11	High Ganges Riv FP		
12	Low Ganges River FP		
13	Ganges Tidal FP	5 AFEZ Tidal Beel	Barisal, Jhalokati, Pirojpur, Patuakhali Madaripur, Gopalganj, Narail Munsiganj
14	Gopalganj KhulBeels		
15	Arial Beel		
16	Middle Megh River FL	6 AFEZ Meghna	Kishoreganj, Brahmanbaria, Comilla Chandpur, Laksmipur Chittagong, Feni, Noakhali, Bhola
17	Lower Megh River FL		
18	Young Megh Estu FP		
19	Old Megh Estua FP	7 AFEZ Haorbasin	Kishoreganj, Habiganj, GComilla GNoakhali, Sylhet, Moulvibazar Sunamganj, Habiganj, Netrakona
20	Eastern Sur-Kushi FP		
21	Sylhet Basin		
22	North and East pied	8 AFEZ Pied Coastal	Sher, Netra, Sunam, Sylh, Moulvibazar Chittagong, Feni, Coxsbazar
23	Chitt Coastal plain		
24	Saint Martin Coral Is		
25	Level Barind Tract	9 AFEZ Barind	Joypurhat, Bogra, Rajshahi, Nowabganj Dinajpur, Rangpur
26	High Barind Tract		
27	North east Barind		
28	Madhupur Tract	10 AFEZ Madhuhill	Dhaka, Gazipur, Narsingdi, Tangail, Khagrachari, Rangamati, Bandarban, Mbazar, GChitt, Habiganj, Brahmanbaria
29	North and East hills		
30	Akhaura terrace		

IV. RESULTS AND DISCUSSION

Table 1: Total species type of the AGF plants studied

	AEZ	Homestead Institute Roof	Roads Embankment	Crop field	Woodlot Forests	Total
1 AFEZ Hima Tista	1,2,3	MPT	Fruitmix	Kapok	Nuts	39
2 AFEZ Korotoa Atrai	4,5,6	Mixed	Ornam	Legume	Sissoo	42
3 AFEZ Brahmaputra	7,8,9	Timb fruit	Timbmix	Kapok	Bamboo	36
4AFEZ Ganges	10,11, 12	Mango+	Palms	Palms	Mehagony	47
5 AFEZ Tidal beel	13,14, 15	Marsh	Fuel	Elder	Palms	23
6 AFEZ Meghna	16,17, 18	Nut+	Legume	Hijol	Telikodom	32
7 AFEZ Haorbasin	19,20, 21	Marsh	Fuel	Hijol	Hijol	10
8 AFEZ Pied Coastal	22,23, 24	Nut+	Nutpalm	Hogplum	Ebony	19
9 AFEZ Barind	25,26, 27	MPT	Koroi	Mixed	Palms	52
10 AFEZ Maduhill	28,29, 30	Jack +	Mixed	Mixed	Bamboo	75

The obtained result from the total number of species found in the system given in the Table 1 and the Fig 1 shows that the 10 AFEZ Maduhill allowed maximum number of tree species 75 as highest, the lowest being 10 for 7 AFEZ Haorbasin which explained mainly due to land elevation form highland to lowland.

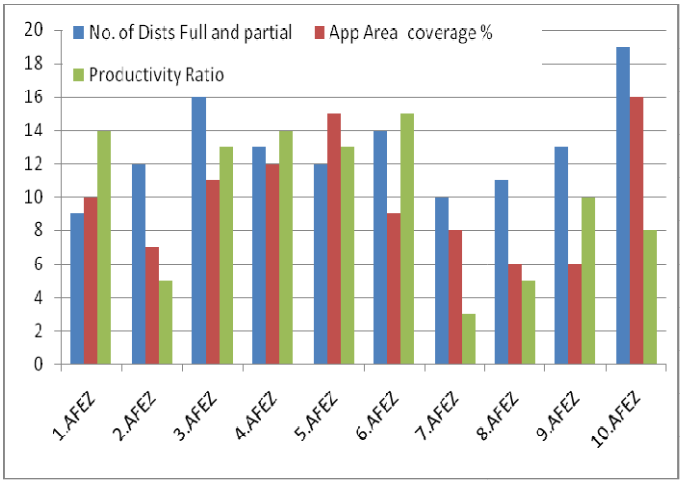

Fig: 1: Total species type of the AGF plants studied

Table 2: Gross Productivity Index

	AEZ	No. of Dists Full and partial	App Area coverage %	Productivity Ratio	Gross Productivity Index
1.AFEZ	1.2.3.	9	10	14	140
2.AFEZ	4.5.6.	12	7	5	42
3.AFEZ	7.8.9.	16	11	13	143
4.AFEZ	10.11.12.	13	12	14	168
5.AFEZ	13.14.15	12	15	13	195
6.AFEZ	16.17.18	14	9	15	135
7.AFEZ	19.20.21	10	8	3	40
8.AFEZ	22.23.24	11	6	5	30
9.AFEZ	25.26.27	13	6	10	60
10. AFEZ	28.29.30	19	16	8	128
		129	100	100	108.1

The results show that present productivity Index is only about 108%. The reasons may be: The cropping and AGF activity in large area AEZ is low which should be given more emphasis to increase the productivity index of the country through intensifying the AGF modeling.

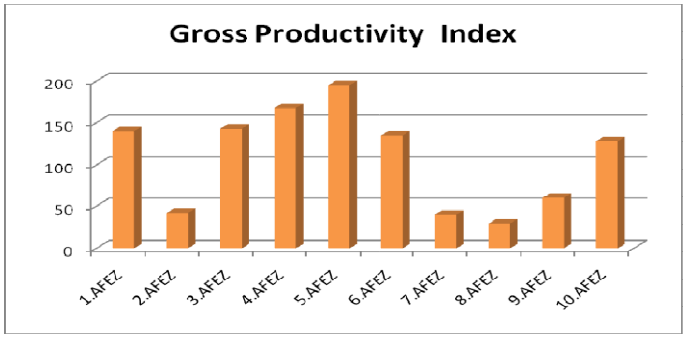

Fig. 2: Total species of the of the AGF systems

Gross Productivity Index (GPI) show that it was highest for AFEZ 5 namely south western Region AEZ 13.14.15, due to its higher coverage and favorable climate for potential growth of numerous Timber and MPT. The lowest was Coastal areas AEZ 22.23.24 being smaller area coverage.

Table 3: Nos .of dominant AGF species as per type and AFEZ cluster zone diversity

	AEZ	Homestead Institute Roof	Roads Embankment	Crop field	Woodlot Forests	Total
1 AFEZ Hima Tista	1,2,3	MPT	Fruitmix	Kapok	Nuts	39
2 AFEZ Korotoa Atrai	4,5,6	Mixed	Ornam	Legume	Sissoo	42
3 AFEZ Brahmaputra	7,8,9	Timb fruit	Timbmix	Kapok	Bamboo	36
4 AFEZ Ganges	10,11 ,12	Mango+	Palms	Palms	Mehagony	47
5 AFEZ Tidal beel	13,14 ,15	Marsh	Fuel	Elder	Palms	23
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7 AFEZ Haorbasin	19,20 ,21	Marsh	Fuel	Hijol	Hijol	10
8 AFEZ Pied Coastal	22,23 ,24	Nut+	Nutpalm	Hogplum	Ebony	19
9 AFEZ Barind	25,26 ,27	MPT	Koroi	Mixed	Palms	52
10 AFEZ Maduhill	28,29 ,30	Jack +	Mixed	Mixed	Teak	75

Table 4: Nos .of dominant Exotic AGF species as per type and AFEZ cluster zone diversity

	AEZ	Homestead Institute Roof	Roads Embankment	Crop field	Woodlot forests	Total
1 AFEZ HimaTista	1.2. .3	MPT	Legume	Legume	Nuts	56
2 AFEZ Korotoa Atrai	4. 5. 6	Mixed	Ornam	Legume Drum Stick	Dragon fruit Bakain	34
3 AFEZ Brahmaputra	7. 8. 9	Fruit	Fruitmix	Eucaly	Lambu	27
4 AFEZ	10.	Mango	Palms	Palms	Mehag	67

Ganges	11.12	+			ony macro	
5 AFEZ Tidal beel	13.14 .15	Teli Kodom	Fuel	Sissoo	Palms	13
6 AFEZ Meghna	16.17 .18	Nut+	Legume	Eucalyptus	Acasia	32
7 AFEZ Haorbasin	19.20 .21	Marsh	Fuel	Lambu	Koroch	04
8 AFEZ Pied Coastal	22.23 .24	Nut+	Nutpalm	Eucalyp	Ebony	11
9 AFEZ Barind	25.25 .27	MPT	Koroi	Mixed	Palms	24
10 AFEZ Maduhill	28.29 .30	Acasia +	Mixed	Mixed	Teak	15

Table 5: AGF Productivity Interaction index

	Homestead Institute Roof	Crop field	Roads Embankment	Wood lot Forests	Mean
Forest AGF Officers Scientists Teachers	46	42	51	78	54.25
DAE Officers Nurseryman	73	31	31	27	40.5
NGO Environ Officer Urban Estate Planners Geographers	42	65	82	69	64.5
Roads and Highway Engineers Civil Officer	29	59	73	58	54.75
Mean	47.5	49.25	59.25	58	53.50

The Table 5 and Fig. 3 & 4 given is the AGF productivity indices show that the NGO Environ Officer Urban Estate Planners Geographers were found to be more concerned being 64.5% for issues relating to AGF development in Bangladesh. The lowest response was found with DAE Officers GOB nurseries. The mean response level was 53% which is just above the working level.

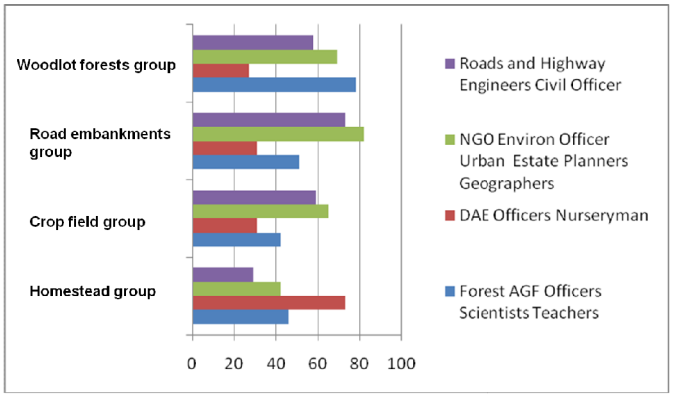

Fig. 3: Productivity Interaction indices as per Respondent groups

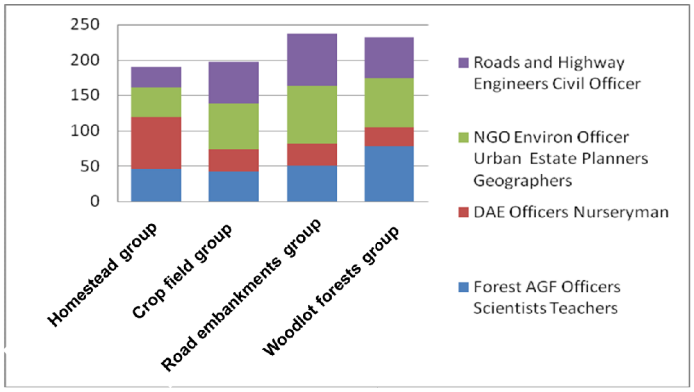

Fig. 4: Productivity Interaction indices as per Respondent groups

V. SUMMARY AND RECOMMENDATIONS

The findings of the research entitled "Studies on the Agroforestry Ecological Zones Modeling Guidelines of Bangladesh" presented in the form of tables and graphs after compilation and analysis are summarized here.

Agriculture and forestry with the traditional approach trying to satisfy the demand of food, fiber, timber and other products, but there is the question of production sustainability and ecological sustainability. Agroecology believed to provide the opportunities to entangle these two disciplines and in place of monoculture shift to polycutural system which tends to lead to the natural ecosystem. In larger agroecological entity agriculture, forestry and agroforestry are treated not as separate disciplines.

The agroecological zones (AEZ) of Bangladesh identified as the zones classified on the basis of land types, soil characteristics, soil water regime, agro-climatic factors. There are 30 AEZ in Bangladesh. This zoning provide the informations which are utilized in many cases for the development of agriculture though there is wide field or prospects for their application in practicing agroforestry for better land-use systems as per as productivity and sustainability are concerned.

Agroforestry is an integrated approach to the production of tree and non-tree crops or/ and animals on the same piece of land. From the dawn of civilization, sustainable food security has been a major human goal. FAO define food security as "physical and economic access to food for all at all times". Agroforestry is uniquely suited to address both the need. Different pattern of agroforestry were common in the early days. For many upland farmers agroforestry was a way of life. Shifting cultivation is believed to have originated in the Neolithic period around 7000 BC. In this system still common in tropical Asia including Bangladesh where trees and agricultural crops are arranged sequentially in time and space to let them grow.

We had a long history of forest plantations; the beginning was around in 1870s in Chittagong Hill Tracts. Before that the 'Taungya' an unique system of forestry plantation in the then Burma under British Empire was started, with an innovative idea of planting Teak with agricultural crops and this was introduced by the Britishers in today's Bangladesh. We have traditional practice in homestead, marginal land and other wastelands where trees are grown in association with other crops.

The present study was undertaken to conduct and assess potential of agroforestry in the clustered agroecological zones of Bangladesh, zone specific suitability of agroforestry species both indigenous and exotics, AGF environmental productivity and to have defined agroforestry modeling guidelines of Bangladesh.

The study was designed as technical and technology adoption and achievement interaction studies using multiple questionnaire guidelines tools. The variables were (i) AEZ site is cluster, (ii) Agroforestry species (iii) AGF productivity. The study area includes all 30 AEZ and 88 sub AEZ and their parameters. Data were collected through face to face interview with questionnaires and also from relevant various secondary sources. Collected data were computerized, analyzed and interpreted using computer program SPSS and Microsoft Excel.

The results show that productivity index is only about 108%. The reason may be the cropping pattern and AGF activity in large area AEZ is low which indicates to give emphasis to increase the productivity index of the country through intensifying the AGF modeling, practicing and managing sustainably.

Profound variability occurs in case of numbers and species as per clustered agroforestry ecological zones. Highest number of tree species (75) found in the 10 AFEZ (Madhu hill) & the lowest (10) being in 7 AFEZ (Haor basin). Gross productivity index (GPI) shows that it was highest for AFEZ 4 namely south western region AEZ 13, 14, 15 due to its higher coverage and favorable climate for potential growth of numerous timber and multipurpose trees. The lowest was coastal area AEZ 22, 23, 24 being smaller area coverage.

As per exotic AGF species are concerned, dominancy found in AFEZ-4 (total no. 67) and quite least number in AFEZ-7 (total no. 04) which indicate the zonal variations also occurred in case of exotics.

Group zone diversity as determined in AFEZ-1, 2, 3, 4 is also profound in total no. of species and bio-mass index. Highest number (83) found in highland sandy loam area and bio-mass index highest in medium highland sandy loam area.

AGF productivity interactions index shows the variability in responses among respondent groups. The present study found the variability of AGF species as per AFEZ, cluster AGF productivity index and gross productivity index, AGF productivity as per respondents groups, environmental productivity characteristics lead to conclude AGF as the better alternative land-use system i.e. agroforestry for production sustainability & ecological sustainability with some specific models for specific clustered AFEZ which are of dynamic in nature. In this regard studies for researches like AGF modeling, silvicultural systems for agorforestry, cultural and Eco tourism values of agroforestry systems may be undertaken.

Recommendations

Agroforestry systems with more innovative ideas may be introduced following specific modeling guidelines for improvement and production sustainability in the areas mentioned below.

1) Homestead garden.
2) Marginal lands e.g. waste and unproductive lands, roadsides, embankment sides, pond sides, institutional lands etc.
3) Low-yield agricultural highland, settled char lands.
4) Crop fields.
5) Private forests both in plains & hills.
6) Government forest both in plains & hills. In this regard ecologically critical zones, watersheds, protected areas as declared by the Government should be excluded.
7) For hill regions agroforestry production systems like agri-silviculture (tree dominant), silvi-horticulutre, agri-silvi-horticulture and silvi-horti-pasture are recommended. In this regard the recommended models are (i) simple plot level model, (ii) dispersed group level model, (iii) complex multi-strata model and land scape ecosystem multi-strata model.
8) Mulberry spp, may be planted in AGF system in road sides, embankment sides, edge of farmlands and other marginal lands for sericulture development.
9) Apiculture though has potentiality and practiced in every zone, it has specific value in the ecosystem of mangroves both natural and plantations may be improved for the sustainability of production and economic benefits.
10) In case of roof garden improvements are needed in designs to follow as per spatial & temporal arrangements are concerned.
11) In rubber plantation areas multistrata vegetations with some annual crops having economic value may be incorporated.

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Biography

Dr. Md. Shafiul Alam Chowdhury was Ex-Deputy Cheif Conservator of Forests, Forest Department, Government of the People's Republic of Bangladesh. He has been working for Forestry in Bangladesh since 1984. Dr. Chowdhury is engaged in research activities throughout his academic career more than 25 years and has published many research papers, participating international conferences.