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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp. 591-603.

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Full Length Research Paper

Qualitative study of epilithic algal diversity spectrum in Lidder stream of Lidder Valley (Kashmir Himalayas)

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The present study was carried out in Lidder stream in Lidder Valley of Kashmir Himalayas, to show a typical taxonomic composition of epilithic algae. The epilithic algal community was represented by 144 taxa belonging to four classes namely, Bacillariophyceae with104 species (72%), Chlorophyceae with 19 species (13%), Cyanophyceae with 12 species (8%), Euglenophyceae with 4 species (3%) and Phylum Protozoa with 3 species (2%) while classes Chrysophyceae and Dinophyceae contributed 1 species (1%) each. Bacillariophyceae was represented by some dominant forms like *Navicula* (16 species), *Nitzschia* (11 species), *Cymbella* (9 species) and *Gomphonema* (7 species). Among blue green algae (Cyanophyceae), genus *Spirulina* recorded 3 species and *Merismopedia* registered 2 species. While in Chlorophyceae, the highest number of species was documented by genus *Cosmarium* (3 species), moreover *Closterium*, *Euastrum* and *Ulothrix* registered 2 species each. Bacillariophyceae was the predominant class at all the sites with the highest contribution of 104 species at sites S1c, S2d, S2g and S4 (first year) and S1a, S1b, S2d, S2e, S2f, S2g, and S4 (second year) while the lowest of 98 species was recorded at site S3 during the entire study, the rest groups were moderately to least represented.

Key words: Taxonomic, epilithic algae, Lidder Valley, Kashmir, Himalayas.

INTRODUCTION

The high altitude, spindle shaped, flat bottomed Kashmir Valley of tectonic origin is a unique natural region, lying within the north-west tip of the oriental stretch with temperate cum sub-mediterranean climate. It is situated in the western Himalayan range between 33° 20’ and 34° 54’N latitudes and 73° 55’ and 75° 35’E longitudes at an average altitude of 1,550 (a.s.l). This beautiful Kashmir Valley is transversed by lone river namely Jhelum (solitary river system of the Kashmir valley and one of the major tributaries of the river Indus).

The major tributaries of the River Jhelum are Lidder, Sindh, Vishav, Sandran, Erin, Romoush and Rambiara. Among these tributaries, Lidder stream is a major right bank tributary which runs through the beautiful side valley known as “Lidder valley”. Lidder valley, being the great tourist hub in Kashmir and base camp, route to the Amarnath cave is subjected to heavy anthropogenic pressure resulting in the deterioration of entire landscape

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Table 1. Geographical co-ordinates and altitude of different sampling sites.

Sampling station name	Geographical co-ordinates	Average altitude
Site S1a (Chandanwari)	34^o 04´72˝ (EW) and 75^o 25´ 04˝ (NS)	2,596 m (a.s.l)
Site S1b (Betab valley)	34^o 04´ 78˝ (EW) and 75^o 24´ 61˝ (NS)	2,402 m (a.s.l)
Site S1c (Laripora military camp)	34^o 01´ 83˝ (EW) and 75^o 19´ 19˝ (NS)	2,213 m (a.s.l)
Site 2d (Aru village)	34^o 05´ 18˝ (EW) and 75^o 15´ 77˝ (NS)	2,361 m (a.s.l)
Site S2e (Bed rock site)	34^o 03´ 97˝ (EW) and 75^o 01´ 25˝ (NS)	2,260 m (a.s.l)
Site S2f (Above power station dam)	34^o 03´ 83˝ (EW) and 75^o 19´ 82˝ (NS)	2,144 m (a.s.l)
Site S2g (Below power station dam)	34^o 03´ 50˝ (EW) and 75^o 19´ 03˝ (NS)	2,122 m (a.s.l)
Site S3 (West-east Lidder confluence)	34^o 00´ 43˝ (EW) and 75^o 19´ 00˝ (NS)	2,120 m (a.s.l)
Site S4 (Langanbal village)	33^o 58´ 24˝ (EW) and 75^o 18´ 80˝ (NS)	2,070 m (a.s.l)
Site S5 (Bumzoo village)	33^o 55´ 56˝ (EW) and 75^o 17´ 93˝ (NS	1,986 m (a.s.l)
Site S6 (Srigufwara village)	33^o 50´ 02˝ (EW) and 75^o 16´ 81˝ (NS)	1,910 m (a.s.l)
Site S7 (Aishmuqam below)	33^o 46´ 33˝ (EW) and 75^o 14´ 53˝ (NS)	1,867 m (a.s.l)
Site S8 (Sangam confluence)	33^o 30´ 06˝ (EW) and 75^o 11´ 12˝ (NS)	1,598 m (a.s.l)

and streamscape. Lidder stream is at the receiving end of all the wastes produced from the terrestrial land posing great threat to the fragile stream ecosystem. The present work is proposed to study the taxonomical composition of epilithic algae of the stream which can be later taken as base line study to collate it with future studies.

Study area and sites

Lidder stream is about 105 km long having two tributaries- the east Lidder stream and the west Lidder stream. In which the east Lidder stream is formed by snow covered mountain torrents of Panjtarni range and originates from the high altitude glacier fed Sheshnag Lake. On the other side are Kolhoi glaciers flowing from the north towards the northeast and unites with west Lidder tributary at Pahalgam town. The west Lidder stream, originating from Tarsar Lake (glacial fed lake) and other allied glaciers, flows torrentially through Lidderwat and Aru and unites with the east Lidder. After the junction of these torrents, just south of the Pahalgam town, the stream flows in a southwesterly direction on a steep gradient with highest turbulence, finally merges into the River Jhelum at Gur near Khanabal (Anantnag). Thirteen sampling sites (Table 1) were selected on the basis of maximum impact of riparian zone, sediment type, habitat type (riffle, pool and run), impoundment and human habitation on stream system (Figure 1).

MATERIALS AND METHODS

Epilithon were collected by scratching 3 to 5 cm^2 of substratum. The scratched samples were collected in plastic viles containing 30 ml of distal water and later few drops of formalin (4%) or Lugol's solution were added to ensure absolute preservation. Then, the samples were transported to laboratory for qualitative and quantitative analysis.

The preserved samples were further diluted with distilled water (1 ml of sample and 9 ml of distilled water). The qualitative and quantitative enumeration of epilithon was done by counting 1 ml of diluted sample in Sedgwick after counting cell (1 ml capacity). The unicellular organisms were counted as unit per centimeter square (unit cm^{-2}) while in the case of filamentous forms like Chlorophyceae and Cyanophyceae, one filament of specific unit (less than 11 units) was recorded as single cells. A binocular compound microscope was employed for the identification of epilithon with eyepieces of 10 to 40x power. The microscope was calibrated using an ocular micrometer. Epilithon were identified using the standard taxonomic keys of Edmondson (1959), Prescott (1978), Cox (1996) and Biggs (2000).

RESULTS AND DISCUSSION

Diversity of periphyton remained low as compared to lentic systems which might be due to shear stress in the lotic system. In the present study, epilithon component of periphyton makes the major proportion of primary producers. The entire studied stretch of Lidder stream was represented by 144 species of epilithon belonging to Bacillariophyceae, Chlorophyceae, Cyanophyceae, Dinophyceae, Euglenophyceae, Chrysophyceae and Protozoa. Based on the species percentage contribution, Bacillariophyceae was the most dominant class being represented by 104 species (72%), followed by Chlorophyceae with 19 species (13%), Cyanophyceae with 12 species (8%), Euglenophyceae with 4 species (3%) and Phylum Protozoa with 3 species (2%). Classes Chrysophyceae and Dinophyceae of algae contributed 1 species (1%) each (Figure 2). Bacillariophyceae was the most abundant species rich group and represented by some dominant forms like *Navicula* (*Navicula acicularis, Navicula apiculata, Navicula cancelata, Navicula coniformis, Navicula cuspidate, Navicula exilis, Navicula hungarica, Navicula lanceolata, Navicula phylepta, Navicula rhynchocephata, Navicula rostellata, Navicula*

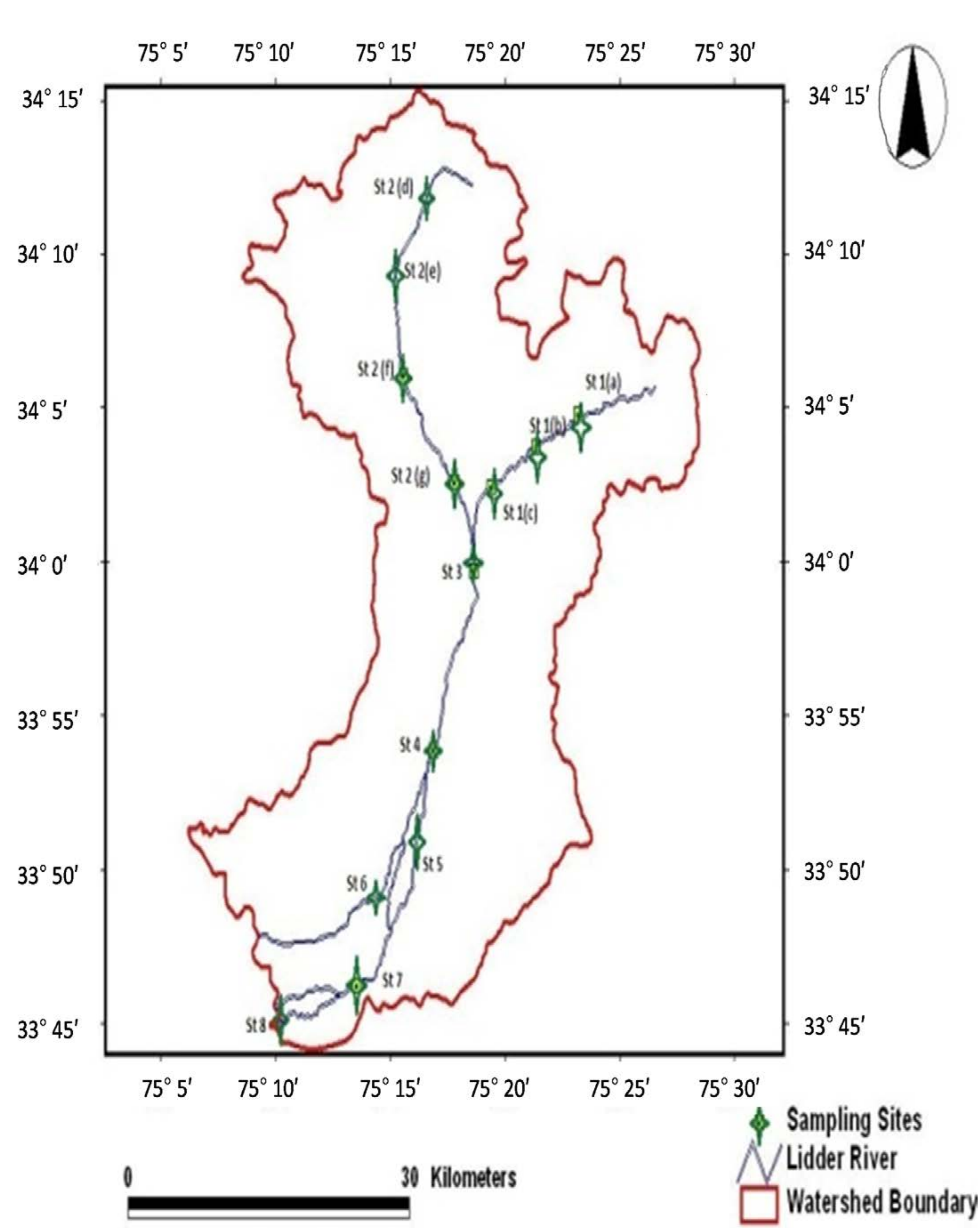

Figure 1. Sampling sites on Lidder stream.

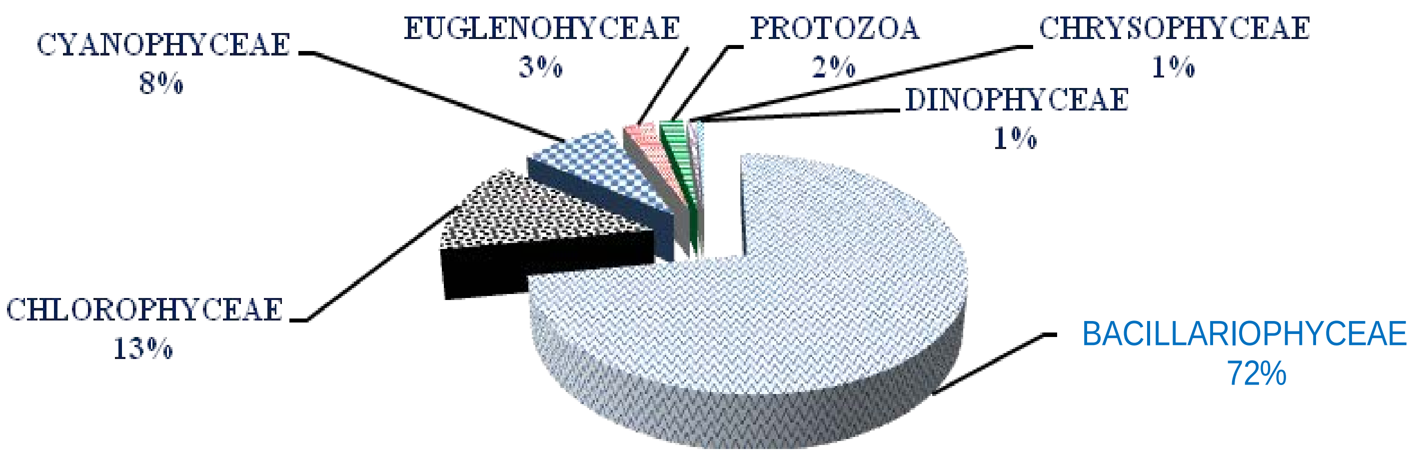

Figure 2. Overall percentage contribution.

submrinuscua, Navicula subrhyncocephala, Navicula subtilissima, Navicula sp., *Naviculata cinta*), *Nitzschia* (*Nitzschia amphibia, Nitzschia angustata, Nitzschia fasciculate, Nitzschia fruslulum, Nitzschia gisela, Nitzschia palea, Nitzschia panduriformis, Nitzschia sigma, Nitzschia uitrea, Nitzschia umbonata, Nitzschia* sp.), *Cymbella* (*Cymbella affinis, Cymbella cistula, Cymbella interrupta, Cymbella lanceolata, Cymbella naviculiformis, Cymbella tumida, Cymbella ventricosa, Cymbella vitra, Cymbella* sp.) and *Gomphonema* (*Gomphonema fenestrate, Gomphonema germinatum, Gomphonema girdle, Gomphonema natum, Gomphonema subtile, Gomphonema truncatum, Gomphonema* sp.). Similarly *Amphora*, *Diatoma*, *Epithemia* and *Synedra* registered 4 species each while *Cocconies*, *Cyclotella*, *Fragilaria*, *Gyrosigma* and *Surirella* listed 3 species each. *Achnanthes*, *Achnanthidium, Ceratonies*, *Didymosphenia*, *Eunotia*, *Hannia*, *Neidium*, *Pinnularia*, *Rhizoclonium*, *Tabellaria* and *Liemophora* were represented by 2 species each. *Cymatopleura*, *Denticula*, *Hantzschia*, *Meriodion, Rhoicosphenia*, *Stauronies*, *Enyonema* and *Placoneis* registered only 1 species each and were least represented in the class (Table 2). While in Chlorophyceae, highest number of species was documented by *Cosmarium* (3 species), *Closterium*, *Euastrum* and *Ulothrix* registered 2 species each. Similarly, taxa like *Zygnema*, *Spirogyra*, *Hormidium*, *Hydrodictyon, Microspora*, *Oedogonium*, *Pleurotaneium*, *Chlorohormidium*, *Cylindrocapsa* and *Desmidium*, were represented by 1 species each. Among blue green algae (Cyanophyceae), genus *Spirulina* recorded 3 species and *Merismopedia* registered 2 species while *Myxosarcina*, *Anabaena*, *Microcystis*, *Nodularia*, *Oscillatoria*, *Rivularia* and *Nostoc* documented only 1 species each.

On the basis of species percentage contribution, the sequence of dominance followed the following trend: Bacillariophyceae (72%) > Chlorophyceae (13%) > Cyanophyceae (8%) > Euglenophyceae (3%) > Protozoa (2%) > Chrysophyceae (1%) = Dinophyceae (1%).

Discernable temporal and spatial variations were evinced during the two years of study and thus the qualitative (diversity) spectrum of epilithon at different sites revealed a distinct frame of diversity in Lidder stream. Bacillariophyceae was the predominant class at all the sites with the highest contribution of 104 species at sites S1c, S2d, S2g and S4 (first year) and S1a, S1b, S2d, S2e, S2f, S2g, and S4 (second year) while the lowest of 98 species were recorded at site S3 during the entire study (Table 3). Chlorophyceae listed a maximum number of species (19 species) at all sites except at sites S1b, S2e and S2f (first year) which registered 18 species each, and 17 species at site S2e (second year). Cyanophyceae registered a maximum of 12 species at each of the sites S1c, S2d, S2f, S3, S4 and S5 during the first study year, while in the second year of study (2008-09), similar number of species were recorded at sites S1a, S1b, S1c, S1e, S2f, S2g, S3, S4, S5, S6 and S7. Euglenophyceae and Protozoa contributed only a limited number of species (4 and 3 species, respectively) at most of the sites. Chrysophyceae and Dinophyceae were least representing classes with total contribution of 1 species each at all sites during the two years of study (Table 3).

Dominance of Bacillariophyceae may be attributed to the presence of good concentration of SiO_2 in Lidder stream which probably helps in the formation of frustules as also reported by Wetzel and Likens (2000). Silica or silicon dioxide (SiO_2) is a key micronutrient in diatom production. Silica concentrations can limit diatom production if concentrations become depleted in surface waters. The depletion of silica tends to occur more often in lakes and reservoirs than in running waters (Cambers and Ghina, 2005). Declines in the surface water silica levels usually lead to a rapid decline in the populations of diatoms. Since Bacillariophyceae shows prolific growth in cold waters, Lidder stream (cold water stream) supports abundant growth of these taxa (Rao, 1995). Importance of calcium in determining the distribution of Bacillariophyceae is an acclaimed factor by Zafar (1967).

Table 2. Species composition of epilithon in the whole Lidder stream.

Class	Genus	No. of species	Class	Genus	No. of species
	Achnanthes	**2**		*Chlorohormidium*	1
	Achnanthidium	**2**		*Closterium*	2
	Amphora	**4**		*Cosmarium*	3
	Ceratonies	**2**		*Cylindrocapsa*	1
	Cocconies	**3**		*Desmidium*	1
	Cyclotella	**3**		*Euastrum*	2
	Cymatopleura	**1**	**Chlorophyceae**	*Hormidium*	1
	Cymbella	**9**		*Hydrodictyon*	1
	Denticula	**1**		*Microspora*	1
	Diatoma	**4**		*Oedogonium*	1
	Didymosphenia	**2**		*Pleurotaneium*	1
	Enyonema	**1**		*Spirogyra*	1
	Epithemia	**4**		*Ulothrix*	2
	Eunotia	**2**		*Zygnema*	1
	Fragilaria	**3**	**Total**	**14**	**19**
	Gomphonema	**7**			
Bacillariophyceae	*Gyrosigma*	**3**		*Anabaena*	1
	Hantzschia	**1**		*Merismopedia*	2
	Hannia	**2**		*Microcystis*	1
	Liemophora	**2**		*Myxosarcina*	1
	Meriodion	**1**	**Cyanophyceae**	*Nodularia*	1
	Navicula	**16**		*Nostoc*	1
	Neidium	**2**		*Oscillatoria*	1
	Nitzschia	**11**		*Rivularia*	1
	Pinnularia	**2**		*Spirulina*	3
	Placoneis	**1**	**Total**	**9**	**12**
	Rhizoclonium	**2**			
	Rhoicosphenia	**1**	**Euglenohpyceae**	*Euglena*	4
	Stauronies	**1**	**Total**	**1**	**4**
	Surirella	**3**	**Chrysophyceae**	*Dinobryon*	1
	Synedra	**4**	**Total**	**1**	**1**
	Tabellaria	**2**	**Dinophyceae**	*Ceratium*	1
			Total	**1**	**1**
			Phylum	*Arcella*	1
Total	**32**	**104**	**Protozoa**	*Coleps*	1
				Diffuligia	1
			Total	**3**	**3**

In the present investigation, high calcium content seems to favor the dominance of Bacillariophyceae (104 species). The presence of indicator diatom species like Navicula, Nitzschia and Cymbella in the study with high calcium concentration clearly indicated that this has been affected by lime quarrying to some extent. Celekli and Kulkoyluoglu (2007) reported that above species could tolerate high calcium concentration in water and they were known as calciphiles or calcium loving organisms. The sub dominance position of green algae in present study might be due to light availability, the most probable reason for the greater proportions of Chlorophyceae may be attributed to the clear water in the studied streams, which provide better light conditions for the growth of group (Allan, 1995), water depth and current velocity (Biggs, 1996; Potapova et al., 2005), light, shading and temperature (Kadhim et al., 2013; Salman et al., 2013), grazing by invertebrate animals (Power, 1990) and sufficient historical time to allow the interactions with these factors to play out. Power (1990) stated that filamentous green algae are natural components of temperate streams and their abundance and seasonal periodicity are influenced by substrate type. Cyanophyceae was dominant during warmer months in Lidder stream as blue-greens has marked tendency to appear in the warm months. Euglenophyceae was sporadic in occurrence at

Table 3. Total diversity of epilithon at different sites in the year 2007-09.

Class	S1a	S1b	S1c	S2d	S2e	S2f	S2g	S3	S4	S5	S6	S7	S8
First Year (2007-08)													
Bacillariophyceae	103	103	104	104	101	103	104	98	104	102	102	102	ns
Chlorophyceae	19	18	19	19	18	18	19	19	19	19	19	19	ns
Cyanophyceae	11	11	12	12	10	12	11	12	12	12	11	11	ns
Dinophyceae	1	1	1	1	1	1	1	1	1	1	1	1	ns
Euglenophyceae	4	4	4	4	2	4	4	3	4	3	3	3	ns
Chrysophyceae	1	1	1	1	1	1	1	1	1	1	1	1	ns
Protozoa	3	3	3	3	3	3	3	2	3	3	3	3	ns
Second Year (2008-09)													
Class	**S1a**	**S1b**	**S1c**	**S2d**	**S2e**	**S2f**	**S2g**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Bacillariophyceae	104	104	100	104	104	104	104	103	104	103	103	103	ns
Chlorophyceae	19	19	19	19	17	19	19	19	19	19	19	19	ns
Cyanophyceae	12	12	12	11	12	12	12	12	12	12	12	12	ns
Dinophyceae	1	1	1	1	1	1	1	1	1	1	1	1	ns
Euglenophyceae	4	4	4	4	4	1	4	3	4	4	4	4	ns
Chrysophyceae	1	1	1	1	1	1	1	1	1	1	1	1	ns
Protozoa	3	3	3	3	3	2	3	3	3	3	3	3	ns

Site S1a, S1b, etc. ns: not sampled.

most of the sites while similar pattern was also seen in rest of the groups.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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A review of potential use of geo-information technologies for cotton supply chain management

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In this paper, we provided an overview of the cotton supply chain management (SCM) and its processes including their inputs/ and outputs. The components of cotton SCM were discussed with their influencing factors. Additionally, we searched relevant literature on the potential use of Geographical Information Technologies (GITs) in cotton supply chain management. According to our findings, there is no study on the utilization of the web to maximize potential of GITs in all components of cotton SCM. GITs are, however, successfully used in intelligent data creation, data management, spatial analysis, agricultural decision support system and partially in supply chain management systems. We found a dire need to integrate applications of GITs in all components of cotton SCM to optimize the use of resources as agriculturalists are utilizing GITs in precision agriculture.

Key words: Cotton supply chain management (CSCM), geographic information system (GIS), geo-information technologies (GITs), crop yield estimation, remote sensing (RS), agriculture.

INTRODUCTION

The cotton supply chain management (CSCM) is a complex system and involves many stakeholders. Sustainable demand and supply require the full participation of each player throughout the chain. Generally, a supply chain involves the processes of converting raw materials into manufactured goods and then to consumers' products. In cotton supply chain, a number of stages are involved; starting from cotton growing, picking, ginning, spinning, knitting or weaving yarn to fabric, conversion of fabric into a final commodity, distribution, selling and then the usage of the product. The primary objective of this review is to understand the complex chain of cotton supply, its components and evaluation of the potential use of GITs in the process. Once the understanding is developed, the potential use of GITs evaluated for improvement of cotton SCM as an outcome.

Cotton supply chain

Both "Components" and "Processes" are essential and integral parts of a supply chain. In addition to the components and processes, there are financial and other

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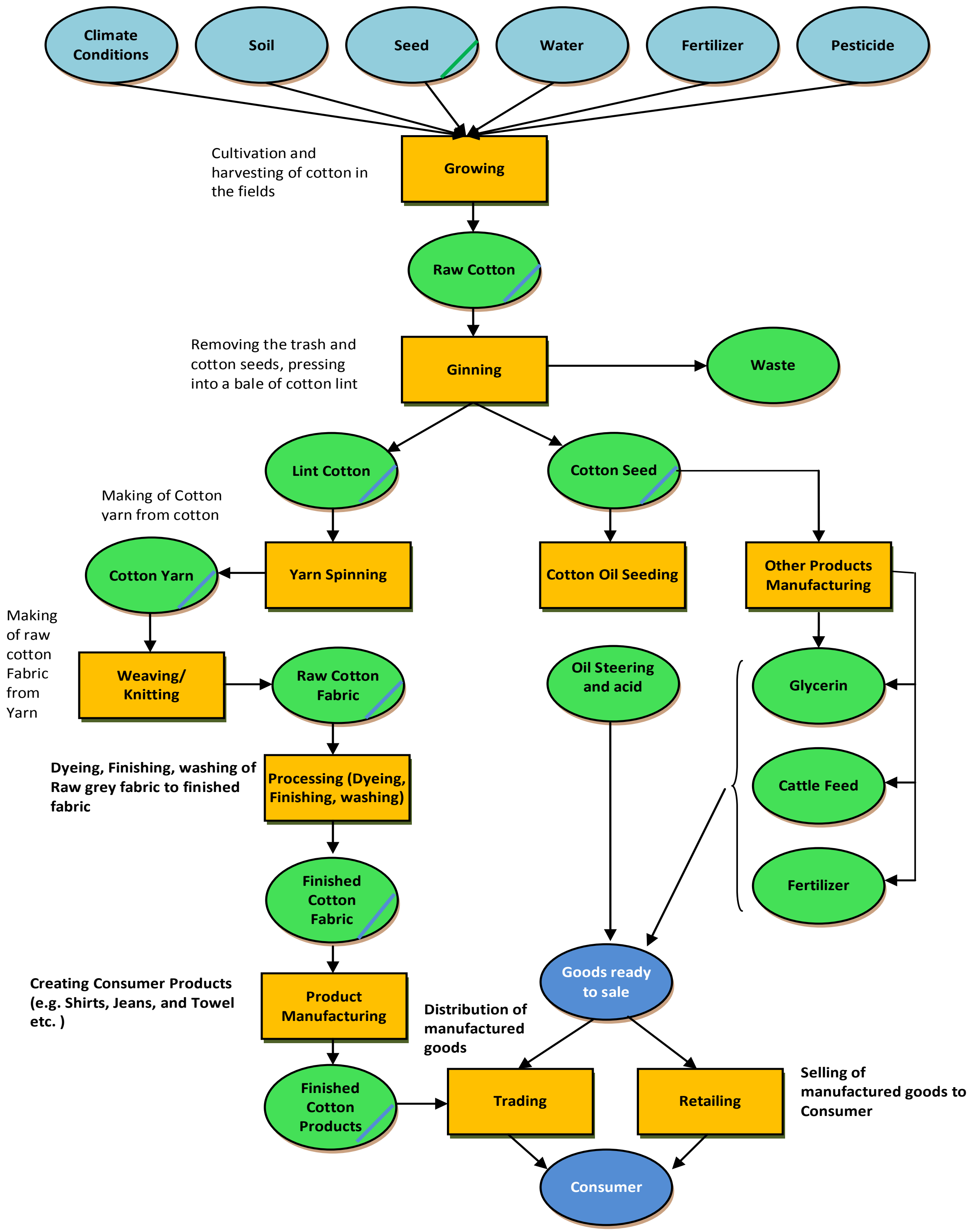

Figure 1. Cotton supply chain.

factors that affect the cotton supply chain. Figure 1 explains the processes of the cotton supply chain with their inputs, outputs and flows marked with arrows.

The purpose of SCM of any commodity is for its sustenance, done by avoiding unrealistic efforts, logistics and losses. Bhan et al. (2010) rated agricultural sustainability as the highest priority throughout the world both in developed or in developing countries Geo-Information Technologies are emerging as useful tools in agricultural sustenance through better management and development strategies. Lal and Pierce (1991) highlighted that the objective of sustainable agriculture is to retain the balance between inherent land resource and crop requirement, which is dependent on sustaining production through optimum utilization of land resource for long period.

Geographic information technologies (GITs)

Shanwad et al. (2004) categorized GITs in precision agriculture into five major groups: Computers, Geographic Information System (GIS), Remote Sensing (RS), Global Positioning System (GPS) and Application control. The subject of Precision Agriculture covers a wide range of issue like variability of the soil resource base, climate conditions, plant genetics, spatio-temporal diversity of crops, machinery performance, irrigations performance and scheduling; crop health and stress assessments; performance evaluation of pesticides and fertilizers; spatial variability of pests and other crop diseases; yield forecasting and production estimations etc. Precision agriculture must fit the needs and capabilities of the farmer and must be profitable. Therefore, there is a strong need to understand the applicability of GITs in every sector of agricultural supply chain management to lower the risks of shortfall and to manage the sources. Dailey (2010) acknowledged in his article that GIT serves as a valuable tool in Supply Chain Risk Management (SCRM) due to its visual analysis. It eventually helps managers and decision makers to prepare for response to any risk/threats in their supply chain operations.

Zhang et al. (2002) discussed the benefits of the technological advancement of current industrial age for agriculture production systems. Mechanization and synthesized fertilizers used for agriculture production systems gained due to this industrial age advancement. Genetic engineering and automation are available in this technological age. GITs potentially used in precision agriculture are used in the information age by integrating other technological advances (Whelan et al., 1997). Spatial and temporal variability are now analyzed by applying advanced geostatistical methods (Pena-Yewtukhiw et al., 2000). Werner et al. (2000) explored the incorporated crop-modeling techniques for fertilizer prescription using yield potential maps developed as a base.

SCM functions involve material procurement, transformations of materials into intermediate and finished products, and then the delivery to customers. For Cotton Supply Chain Management, GITs are tools that can be used to forecast cotton production, map acreages, ginners, spinners, manufacturers, warehouse locations, retailers and distribution centers, and routing of vehicles in particular. Additionally, GITs can be used to analyze the influencing criteria of each actor in the supply chain.

MATERIALS AND METHODS

Literature searched

We did a systematic literature search in Google.com and ScienceDirect.com to get extensive knowledge about the cotton supply chain, its components and the potential applicability of GITs in the cotton supply chain management. The literature search period was from July 2009 to May 2010. The “Cotton Supply Chain in Sindh”, ‘‘GIS in Cotton Supply Chain’’, ‘‘Remote Sensing and GIS in Cotton Supply Chain’’, ‘‘Use of GIS in Cotton supply chain’’, “Supply Chain Management”, Components of supply Chain Management”, “GIS in Ginning Industry”, “GIS in Cotton Transportation”, “GIS in Agriculture” and “GIS and Remote Sensing for Cotton Yield estimations” were the keywords used in this research.

It was not possible to get complete information and knowledge on cotton supply chain contents from research papers. In addition to research work, we used presentations of different conferences, agri-reports and literature available on different URLs of Supply Chain Management Company’s website. In this regard, the identified research papers are limited compared to the literature found in other formats. While searching Cotton SCM, most of the research papers focus on Cotton yield/ Production/Acreage estimation techniques and forecasting. Keeping in view the objective of the study, we included only those research papers, which directly or indirectly discussed GITs in the agriculture supply chain including cotton. Considering the emerging application of GITs in Agriculture and SCM, the literature searched spans from 1995 to 2010.

Identified studies

Five (5) spatial studies of SCM were found in literature and 20 potential GIT studies were extracted in general. However, no studies focus on all components of Cotton Supply Chain Management, instead most of the studies focus on one or a few components of the SCM. Table 1 contains some key findings from Cotton SCM studies.

Fannin et al. (2010) discussed the use of GITs in Louisiana–USA in assessing the spatially variable capability of the cotton ginning infrastructure. For this purpose, they compare cotton field locations with cotton gin locations in spatial canvas by applying Geo-Information technology. Mwasiagi et al. (2008) utilized GIT for cotton yield production in Kenya; they used it to describe agricultural efficiency in the cotton-growing industry. They also applied different spatially enabled resource management methods in this regard. They designed an artificial neural network model to predict cotton yield by using selected cotton-growing cost factors. The performance of the neural network model was satisfactory in predicting cotton yield with minimum errors; a correlation coefficient between network output and actual yield was 0.945.

Simpson et al. (2006) analyzed the transport of cottonseed using GITs in Texas. In this study, Geo-Information Technology was used to route trucks along shortest distance and to decide the quickest or alternate routes to the field and gin area to save time and money. Cotton producing areas, ginning units and transportation network were mapped using ArcGIS by integration of Satellite Images. To analyze the ginning service areas and capability of regional transport (in terms of transport distance and cost), the transport analyst feature in ArcGIS was used.

Sambrani and Subhas (2009) appraised the GITs capability from manager’s perspective for Routing Analysis in Supply Chain

Table 1. Characterization of identified studies for GITs applications for cotton SCM.

Reference	Year	Study area	Data	Methodology	GITs Applied For
Farida Perveen et al.	Accessed on Feb 2010	Bangladesh	Terra/ASTER, SRTM	Multi-Criteria Evaluation (MCE) & GIS approach	Crop Land Suitability
Fannin, et al.	2010	Louisiana	Cotton Ginning statistics, Cotton GIS data	Gin and Cotton Field Distance Analysis	Cotton Ginning Supply Measurement
Bhan et al.	2010	India	GIS Research Literature	Literature Review	Sustainable Agricultural Management
Siva Subramanian	2009	India	IRS Remote Sensing and Market arrival data	Supervised and unsupervised classification with GPS Data, GIS based comparison	Comparison of remote sensing based estimated production with the crop arrival in the market.
Vinod et al.	2009	Dharwad district, India	Transportation, Settlement and Satellite Images	SDSS for route analysis	Routing Analysis in Supply Chain Management (SCM)
Gang Pan et al.	2009	Loess Plateau, China	QuickBird imagery	Integrating QuickBird imagery with a production efficiency model (PEM)	Crop yield estimation
McKiniona et al.	2009	Mississippi, USA	Multispectral imaging using cameras mounted on fixed-wing aircraft	NDVI based spatially variable insecticide application maps	Spatially variable insecticide applications to cotton control insect pests
Pereira et al.	2009	Fergana Valley, Central Asia	Meteorological data concerning precipitation, Crop data, Multiyear soil data	ISAREG model	Irrigation scheduling strategies for cotton
Dong Qinghan et al.	2008	North China Plain	Landsat TM, IRS-P6 AWiFS, SPOT-Vegetation	Hard and Sub-Pixel Classification of RS Data	Crop acreage assessment
Mwasiagi et al.	2008	Kenya	District agricultural data	Artificial neural network model	Prediction of cotton yield
Bandhopadhyay et al.	2008	Nagpur District, India	Remote sensing (Resourcesat-1 LISS III) and spatial agro-climatic data	Infocrop-cotton simulation model	Predicting cotton production
Sharifia et al.	2008	Iran	MODIS/Aqua images and daily meteorological data	Spatial Decision Support System of RS based Bio-Physical Models	Natural Damage Assessment of Crops

Table 1. Contd.

Reference	Year	Study area	Data	Methodology	GITs Applied For
Sharifia et al., 2008	2008	Iran	MODIS/Aqua images and daily meteorological data	Spatial Decision Support System of RS based Bio-Physical Models	Natural Damage Assessment of Crops
Robert	2008	Brisbane, Australia	GIS Research Literature	Analytical review	For precision agriculture and supply chain management
Falkenberg et al.	2007	Uvalde, Texas	Field study & pivot-installed-remote sensing, 30 IRT Data	IRT canopy temperature integration with weather and irrigation data in GIS	Irrigation management of cotton
Nardi et al.	2006	Argentina	Country level Crop & Transportation data	General Algebraic Modeling System, GAMS	Optimization supply chain management of grains
Simpson et al.	2006	Texas	Color near infrared (NIR) aerial photos, Transportation Data	Shortest, quickest distance and cost analysis using ArcGIS network extension	Seed Cotton Transport Analysis
Jayroe et al.	2005	Jonesboro, Arkansas	Aerial images were acquired using multi-spectral camera	NDVI based Classification Method	Crop Production Evaluation
Ferencz et al.	2004	Hungary	Landsat, NOAA, AVHRR	Vegetation Index (General Yield Unified Reference Index (GYURI)	Crop yield estimation
Thomasson et al.	2004	Mississippi	Landsat, 30-m Satellite Data	Gossym cotton growth model	Estimating plant height for Cotton Growth
Shanwad et al.	2004	india	GIS Research Literature	Literature Review	Precision Agriculture
Toulios et al.	2003	Palamas, Greece	SPOT satellite with hand-held radiometer data	Agrometeorological Modeling	Crop Yield Estimation
Ronald et al.	2002	U.S	Landsat 5 and 7 Satellite Images	A Modified Supervised Classification Technique	Crop acreage assessment
Zhang et al.	2002	worldwide	GIS Research Literature	Literature Review	Precision Agriculture
Nadeem et al.	1998	MianChannun	Field data	GIS based surface maps	Spatial analysis of Cotton Leaf Curl Virus
Farhad	1995	Iran	Landsat TM data	Land cover classification	Agricultural Resource Management

Management (SCM) in Dharwad District of Karnataka State, India. The Spatial Decision Support System (SDSS) was developed for this purpose using Visual Basic 6 as the front-end tool with spatial data on transport and settlements. Shortest and alternate path module was developed by modification of the Dijkstra routing algorithm.

Lorimer (2008) explained the usage of GPS from grower to onward processing levels in cropping agriculture chains. Subramanian (2007) presented the idea of GITs Application in Supply Chain Management of agriculture sector. IRS P6 AWiFS satellite images with spatial resolution of 56m were used for agricultural acreage. Medium and high-resolution satellite images of IRS series 1C, 1D, P6 LISS III and LISS IV were used to extract remotely sensed spatial information. Field observations of secondary and primary sources were incorporated such as topography from survey of India - 1:50,000 map series, district wise agriculture statistics and agro-market data from district/state agriculture boards, and farmer's information from sample surveys. The adopted methodology for this study depicts the benefit of GITs based supply chain management as an easy utility for future supply chain management model in complex functions.

Nardi et al. (2006) studied the optimization of supply chain management of grains using ArcGIS in Argentina by applying General Algebraic Modeling System (GAMS). To minimize the transportation and storage costs of soya bean including its by-products, a GITs based constrained linear programming model was developed and successfully implemented.

Sharifia et al. (2008) presented the recent developments in remote sensing technology in biophysical science; they were used to develop an appropriate model for assessment of impacts of natural hazard on agricultural production. For this purpose, a yield model is developed and applied to simulate the biomass production of rice in the growing period. High and low-resolution multi-temporal satellite images were used along with daily meteorological data in the growing period; SEBAL model (Bastiaanssen and Ali, 2003; Zwart and Bastiaanssen, 2007) was also implemented.

RESULTS AND DISCUSSION

It is difficult to discuss all the potential applications of GITs related to cotton SCM. However, discussions excerpted from literature are organized in the following headings: Intelligence data creation; data management; spatial analysis; decision support system; supply chain management system.

Intelligent data creation

To take the right decisions at the right time and for crop cultivation, harvesting, fertilizers and pesticide use, irrigation water management, crop health assessments and yield forecasting, crop acreage estimations, crop market evaluations, supply and demand assessments are few examples of agricultural intelligence data, which are required for sustainable agriculture and supply chain management of agriculture commodity. In the past, an agricultural intelligence data creation involved long surveys with heavy budget and human resource that lacked accurate and timely results most of the time. With the advent of Space Technology, Satellites and GIS tools as GITs are providing fast, less costly and timely results for agriculture decision makers in developed countries where GITs are applied successfully.

GITs also enable supply chain managers to classify satellite images for the identification of crop types in their target areas. The amount and type of energy emitted from each type of crop at each growth stage differs based on the crops. The high-resolution images like the Landsat Thematic Mapper, IRS, Ikonos, and QuickBird are widely used for supervised and unsupervised classifications with a number of spectral indices for delineating crop types in the same agricultural regions for accurate production estimations.

The most critical part of the Cotton Supply Chain management is acreage estimation. The secondary data sources usually based on surveys are by some means costly and inefficient. By applying a number of GITS methodologies with different Remote Sensing data, the areas under cultivation of a particular crop can easily be identified and mapped.

Craig (2002) evaluates the remotely sensed multi-spectral imagery of Landsat 5TM with the Landsat 7 ETM+ to distinguish type of crop and acreage estimation. Comparisons are done for different types of crop areas in several states, using images that are only one day apart. In this study, he used modified supervised pattern recognition to discriminate signature of each type of crop and maximum likelihood for classification and area estimation under each crop in the study area.

Qinghan et al. (2008) also worked on crop acreage assessment in China. This study evaluates the potential application of GITs to estimate large crops. For this purpose, two approaches were applied. Multi-temporal high-resolution images (LANDSAT TM Satellite Images) were classified as the first method. To get better cost-efficient results, the low-resolution satellite images were classified at sub-pixel level as second method. At last, the sub-pixel was classified as SPOT-VEGETATION data calibrated with the hard-classified Land Sat TM Images of 2005, which provided the cost-efficient early acreage estimation methodology through GITs. Similarly, JIAO et al. (2010) provide an efficient and effective method for crop acreage estimation at a national scale in China. Both high and low-resolution data were incorporated with stratified sampling and classification techniques for crop planting area estimation.

In predicting yield, not only acreage and type of crops are important, but also the health of the crop is the prime influencing factor. Through GITs, the water stress areas can easily be distinguished from the healthy crop areas. This involves the emission of different level of energy from healthy and water stressed crops. There are a number of algorithms appraised by different researchers for healthy crop and stress quantification. McKiniona et al. (2009) investigated the spatially variable GITs use for insecticide and identification of tarnished cotton crop insect pests, Lyguslineolaris, plant bugs in cotton fields.

Falkenberg et al. (2007) assessed the commercial instrument of remote sensing managing the biotic and abiotic stress on cotton (Gossypiumhirsutum L.) at specific sites. Canopy temperature of crops is a key indicator of water stress in plants, and can help in developing an efficient irrigation management system (Moran et al., 1997). The deployment of remote sensing data to generate canopy temperature has been useful in examining plant stress (Michels et al., 1999). Bugbee et al. (1999) highlighted the role of Infrared Thermography (IRT) used to investigate leaf temperatures and thermal stress of cotton (e.g. by Burke et al., 1990). Hatfield and Pinter (1993) and Michels et al. (1999) presented the Aerial ‘‘fly-overs’’ with installed infrared apparatus, and IRTs with tethered balloons. These are employed for detecting water stress in crops by changes in recorded leaf temperature. Near and thermal Infrared (IR) bands of the electromagnetic spectrum are worked out as remote sensing (RS) tools. To determine plant water stress, Near IR (Nixon et al., 1975; Toler et al., 1981) has measured the reflected light in form of wavelengths. Several researchers appraised Thermal Infrared (TIR) as a useful way to determine canopy temperature, which can eventually help with irrigation scheduling for cotton (Wanjura et al., 1992; Wanjura and Mahan, 1994). Toler et al. (1981), Jackson (1986) and Pozdnyakova et al. (2002) affirmed the use of color-infrared satellite imagery to determine ground data, crop yields, yield components, soil properties, and for detection of crop diseases. Only one study revealed the use of GIT in Pakistan viz. Nadeem et al. (1998) as they estimated spatial variability of cotton leaf curl virus in MianChannu by using surface maps.

Steinmetz et al. (1990), Ruddy and Pachepsky (2000), and Bastiaanssen and Ali (2003) present that crop yield estimation is an essential aspect of agricultural intelligent attributes. Determining income and consumption at field scale yield plays a vital role whereas at regional and global scale the cumulative yield helps to take intelligent decisions and planning policies for trading.

Pan et al. (2009) described a method by integrating QuickBirdsatellite imagery with a production efficiency model (PEM) for crop yield estimation in Zhong lianchuan, China. In the production efficiency model (PEM) model, crop yield is a function of the photosynthetic active radiation (PAR), the fraction of absorbed photosynthetically active radiation (fAPAR) and light-use efficiency (LUE). A land cover classification method based on the 0.6 m QuickBirdsatellite imagery is employed to determine class-specific light-use efficiency (LUE). The photosynthetically active radiation (fAPAR) is associated with satellite imagery based spectral vegetation indices (SVI). To estimate crop yields, LUE, fAPAR and incident PAR data are combined in this study.

Ferencz et al. (2004) presented two methods for estimating the yield of different crops in Hungary from satellite remote sensing data. In the first method, selected crop fields as reference are chosen by using Landsat Thematic Mapper (TM) for classification to get crop estimations at field level. General Yield Unified Reference Index (GYURI) was construed by using a fitted double-Gaussian curve to the National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) data for plantation period. The country-level yield data reports with NOAA AVHRR are integrated as second method. The investigated methods are inexpensive and easy for efficient yield estimations.

Bandhopadhyay et al. (2008) also described a methodology to forecast cotton production on a regional basis using the integrated approach of GITs and crop simulation model, that is, Infocrop cotton model. The Infocrop indigenous crop growth simulator model was calibrated and validated to replicate the effect of varied weather, soil, and agronomic management practices on growth, development and cotton yield according to varieties and hybrids by using a number of different field experiments results.

Thomasson et al. (2004) present the GITs capability to predict yield before harvest for better risk management and profitability of the producers. They developed an application interface connecting the Arcview GIS (Geographic Information System) with the cotton crop growth model (Gossym), which allows it to accept inputs (remote-sensing-based plant-height estimates) and provides outputs (predictive yield) on a site-specific basis. Based on this study, the use of remote sensing data for plant height estimations appears reasonable to get better Gossym’s yield prediction forecasts. Toulios et al. (2003) used agro-meteorological model for early crop estimation with field verification data in Greek. The model is based on the linear relationship between the normalized difference vegetation index (NDVI) and the photosynthetically active radiation (PAR). The three years experiment results revealed that the field measurements of estimated yield could be applied with multi-temporal remote sensing data.

Estimation of crop before arrival in market

In the past, there was no method to check crops before being taken to the market; this in due course not only causes financial losses to both the farmer and producers but also to the consumer who eventually suffers from this unsustainable condition of the commodity. The scarcity of wheat in Pakistan is one example of this unstable condition. This is because after getting good production of wheat crops, they are still scarce in the market. This can be eliminated by applying GITs in agriculture to check and balance the actual crop production and arrivals in markets and industries. Subramanian (2009) showed the difference between conventional methods based crop estimation data and remote sensing based estimations. This study leads us towards the answers of authentic questions of data produced from remote sensing.

Guo et al. (2007) demonstrate in their study that agricultural information can be acquired by the combinative methodology of automatic extraction and visual interpretation accurately and speedily through GITs.

Data management

In today's technology age, data management through metadata is significant because it illustrates data expressions that define data and make users to consistently collect, index, query and publish, as well as document the content, quality, source of organization, data format, organization, spatial reference, distribution mechanism and so on (Puntodewo and Salim, 2005). GITs provide direct understanding and insight into how best we can manage agriculture data in its overall supply chain context. The RDBMS technology is useful for integrating the Geo-Spatial data with attribute data to deal with the input, output and flows in supply chain management from grower to consumer level. The Long statistical reports, manual analysis, spreadsheets are now transformed into GIS databases for easy access and effective usage through visual/spatial presentation available not only on Desktop Computers or printed formats but also on WEB portal for worldwide access.

Decision support systems

Every application of GITs in agriculture is special. Certain fundamental principles have been appended. Agriculturalists need to access huge datasets for significant analysis of required agricultural retrievals, irrigation techniques, agro-techniques, agricultural insurance, warehousing, manufacturing, and marketing logistics. Agricul-ture is considered as a new arena for GITs implement-tation; however, remote sensing has been used effect-tively for the last 70 years. The Decision Support tool is best employed in crop suitability site analysis and irriga-tion scheduling using Geo-Spatial and Geo-Temporal analysis.

Perveen et al. (2010) explored cropland suitability analysis for optimal utilization of land resources for sustainable crop production. Agricultural land management and cropping patterns require better development strategies to increase crop production with efficient use of available land resources. In Agriculture-Spatial Decision Support System (Agro-SDSS) various techniques including Multi-Criteria Evaluation through GITs give more stable and precise decisions to the decision makers in order to evaluate all factors at a common platform. This research enables local farmers to select suitable cropping patterns for suitable areas.

Pereira et al. (2009) explore GITs in taking decision concerning cotton irrigation. For high irrigation performance and to reduce water loss by controlling the access of water percolation on the ground, a proper irrigation scheduling is required. Jackson and Tilt, (1968) and Grimes et al. (1969) stated that cotton yields are low due to unnecessary water applications. The most often available studies highlight the bad impacts of water deficiency on growth and yields of cotton crop (Grimes and Yamada, 1982; Gerik et al., 1996; Pettigrew, 2004; Karam et al., 2006; Falkenberg et al., 2007; DeTar, 2008). Many studies that describe the causes of water stress are well known (for example Bruce and Shipp, 1962; Turner et al., 1986; Pettigrew, 2004). Dalton et al. (2001), Howell et al. (2004), Gibb et al. (2004), Bhattarai et al. (2006) and Dagdelen et al. (2006) studied that relationships between methods of irrigation and scheduling provide important information to improve water usage and productivity. Shreder et al. (1977), Doorenbos and Kassam (1979), Ertek and Kanber (2003) and Dagdelen et al. (2006) discussed several functions developed for improved water-yield through GITs.

Spatial analysis

Information compilation is completely location specific in GITs. Geo-referenced data at the farm scale can assist in better decision making to improve crop productivity. The significant aspect is to make use of such data to enhance agro-productivity by choosing the right crop in the right fields or by estimating the amount of inputs necessary for a crop at every stage of growth. The corporate sector, business conventions and governmental rules and regulations have more influence than ever before. A farmer now has to be up-to-date with adequate knowledge regarding farm accounting, subsidy guidelines, agricultural legislation and regulations, taxation, crop insurance to make such key profit analysis.

Jayroe et al., (2005) describe the agriculture spatial information for fertilizer and other chemical applications. The study aimed to research: (i) a correlation verification of data gathered through yield monitor and Satellite Imagery, (ii) the relationship between vegetative growth patterns and soil electrical conductivity, and (iii) a production method of the vegetation map through satellite images used for direct investigation and decisions in mid-season chemical application.

There is always the possibility of natural hazards to crops throughout the growing periods, like excessive rain, droughts, floods etc. The crop at risk can efficiently be determined through GITs. This would make the planners to plan well like; when and what should be imported to reduce instability in Supply Chain of any crop and to provide better services to the consumer.

Sharifia et al., (2008) explain agricultural crop insurance as a key supporting policy for agricultural sustainability in many developed countries because it has a propensity to decrease farmer's risk and shield them against crop failure due to hazards.

A yield model, which simulates the biomass production of crop, was developed and validated to evaluate the impacts of hazards on yield production in growing seasons. High and low resolution multi-temporal satellite data were used with the SEBAL model (Bastiaanssen and Ali 2003; Zwart and Bastiaanssen, 2007) and meteorological data on a daily basis as an important input. The collected data were analyzed and interpreted; the results show maps of potential, actual and deficit evapo-transpiration, biomass production (total dry matter related to stem, leaves, roots and grains), soil moisture and yield reduction caused by severe temperature, drought, the deficit vapor pressure for each decade in the study area to determine the crop at risk.

GITs investigation is not confined to the usage of mapping software to draw points, lines and polygons on a map. Instead, it provides the capability to draw spatial relationships and to distinguish value in each spatial relationship.

The demand and supply planning is the most critical and sensitive part of Supply Chain Management. What is the supply and demand or what are the demands and what will be the supply is a complex question for Supply Chain Manager in the absence of accurate and timely information on the product. GITs help every actor of Cotton Supply Chain by providing near real time estimate data through analysis or by defining the trade, areas of certain crop and the influencing factors.

Supply chain management system

To calculate the current and future demand of a crop, its products and to complete its analysis, crop supply chain is required in a spatial context. If agro-businesses were to employ GITs, eventual benefits would be maximizing the management of the supply chain of crops and minimizing the losses due to unclear predictions. Simpson et al., (2006) in their study developed a GITs based logistics system for cotton transportation from farm to gin through module trucks. Several advantages are identified using a GITs based logistics program in scheduling and routing module vehicles (Simpson, S. Let al., 2006).

A geographic information system (GIS) software package (ArcGIS) was utilized to route trucks along shortest distance, quickest route, or alternate roads to pick up modules in the field and gin area. For this purpose, cotton production, ginning facilities, highways and local roads in the state of Texas were mapped using ArcGIS. Color near infrared (NIR) aerial photos was utilized as well. The transport analyst extension in ArcGIS was used to analyze the gin service areas, transport ability at regional level, which eventually result in cost evaluation for each route.

An efficient supply network would reduce the life cycle of crops in supply chain, and thus reduce costs, improve resource management accountability and distribution. Simpson et al., (2006) practically introduce GITs in this study to improve ability to manage resources for specific delivery requirements on temporal and spatial basis. GIT has potential to network all actors of Cotton Supply Chain with respect to their trade areas and relations with each other for better management and logistics of Cotton Supply Chain.

It is significant to point out here that GeoInformation Technologies are not fully utilized in the field of cotton supply chain management until now. There are not many actors/areas of that supply chain, which benefit from this technology like transportation routing, crop yield, area estimations, and others discussed in previous sections. Full employment of GITs in an efficient supply chain management of cotton is a strong need for today’s world to enhance the capability of agriculture and agribusiness.

Conclusion

After an extensive literature review, it is concluded that Geo-Information Technologies (GITs) offer a valuable range of cotton supply chain management tool. GITs analysis in spatial canvas provides the opportunity to represent visually all required supply chain information in different compatible formats. GITs help decision makers to answer agriculture supply chain management questions like:

1. What is the production of the target crop for a target year?
2. What and where is the demand and supply of that target crop?
3. Where are the markets/processing units located?
4. Where are the raw crops located?
5. What is the transportation cost (both; Money and time) from the farm to the market/Processing units?
6. What is the best route that is, the shortest and safest distance?
7. What are the alternative routes, in case of problems such as traffic congestion, hazards etc., of the selected route?
8. How long will it take to reach delivery locations (Industries)?
9. How can one track goods through the crop supply chain?
10. Which and where are the Consumers (Retailer perspective)

While comparing conventional methods, GIT is more efficient in predicting accurate and timely forecasts for crop yields. On the other hand, presenting cotton supply chain data in the form of a spreadsheet ignores the real world influence of geography on each actor in the supply chain. There is a wide range of GITs software, hardware, tools and extensions to process the large bundle of data easily. Besides these, there are a number of accessible satellite images with and without cost for crop estimations and other GITs applications. Consequently, when supply chain performances are analyzed in GITs framework, the problems are immediately visible with alternatives, such as revolving cropping patterns, spatially variable fertilizer applications, and accurate acreage and yield risk estimations, rerouting to avoid delays in transportation. Proper data help managers and decision makers to achieve their competitive precedence and increase the overall supply chain sustainability and profitability. GITs based maps are not just pictures or mere maps; they are spatially variables. Integration of the spatial data along with the attribute data helps decision makers to do “what-if analysis” and actually see the implication / impact of the result in the supply chain area. The benefits and limitations of applicability of GITs in agriculture SCM are summarized below.

Benefits

More efficient Agriculture Intelligence data creation and central validation.
GITs can play vital role in relating information from grower to consumer.
GITs can limit traders / growers to rely on intermediaries.
GITs based data generation and forecasting are vital for crop risk assessments.
Geospatial based supply and demand analysis and trade area demarcation.
Agro-decision support systems.
Transparency throughout the cotton SCM.

Limitations

Gaps and unorganized secondary data with limited availability.
Cloud free satellite data throughout the growing season.
High resolution satellite images are costly.
GITs provide a standardized environment to integrate the data for numerous cotton supply chain processes. Once spatially validated, the data can be used in many other agro-economic applications, thus adding worth to the data and the chain process overall.

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Woody species diversity under natural forest patches and adjacent enset-coffee based Agroforestry in the Midland of Sidama Zone, Ethiopia

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Agroforestry lands will be the most beneficial to the long-term preservation of biodiversity through preserving native species of plants and animals in tropical countries. Despites its vital roles, the contributions of agroforests and forest patches for biodiversity conservation in Ethiopia have few studded. The aim of this study was to investigate status of woody species diversity in natural forest patches and adjacent Enset-Coffee based agroforestry (ECAF) with particular emphasis on their contributions to biodiversity conservation in midland of Sidama zone, Ethiopia. The two study sites (Wonsho and Shebedino districts) were selected purposively based on presence of forest patches and extensive practices of ECAF. Similarly, the three kebele in each sites were selected based on the presence of natural forest patches. A total of 96 quadrats (48 in each systems), having 20 m x 20 m area were systematically sampled. Our results show that a total of 75 different woody species categorized under 31 families were recorded, of which 43 species under 30 families from the natural forest patches and the remaining 32 species under 21 families from ECAF. Twenty two woody species belonging to 15 families were common to both the natural forest patches and ECAF that makes 58.67% of similarity in woody species composition. Euphorbiaceae family had the highest number of woody species both in the natural forest patches and ECAF. Shannon and Simpson diversity indices of woody species from natural forest patches were significantly ($p < 0.05$) higher than the ones from ECAF. Of all woody species identified, 86.67% were native. Finally, it is concluded that ECAF play a major role in the conservation of native woody species.

Key words: Biodiversity, conservation, native, woody species, similarity.

INTRODUCTION

Natural habitats in the tropics are being converted to agricultural land faster than in any other biome (Whitmore, 1997). These changes can result in the loss of population and species. Consequently, the need for immediate action to design effective strategies to conserve biodiversity is given an attention worldwide. Scientists and policy makers are becoming increasingly aware of the role agroforestry plays in conserving biological diversity in both tropical and temperate regions of the world. The mechanisms by which agroforestry systems contribute to biodiversity have been examined by various authors (McNeely, 2004; Schroth et al., 2004; Harvey and Villalobos, 2007). In general, agroforestry plays five major roles in conserving biodiversity: (1) provides habitat for species that can tolerate a certain level of disturbance; (2) helps preserve germplasm of sensitive species; (3) helps reduce the rates of conversion of natural habitat (4) agroforestry provides connectivity by creating corridors between habitat remnants and (5) helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge. Different authors also promoted *circa situm* conservation via an agroforestry system high in agricultural landscapes ((Boffa et al., 2005; Philpott et al., 2008). This approach focuses on sustainable conservation and utilization of the species. Retention of forest species in agricultural landscapes enhances biodiversity conservation at both species and landscape level (Herve and Vidal, 2008). The preservation of biodiversity was not limited in agroforestry lands. Remnant trees (forest patches) also play an important role in conserving biodiversity within agricultural landscapes, because they provide habitats and resources that are otherwise absent from agricultural landscapes (Harvey and Haber, 1999).

Agroforestry practice in the tropics and sub-tropics started many years ago (Kumar and Nair, 2004; McNeely and Schroth, 2006). In Ethiopia, agroforestry emerged together with agriculture not more than 7000 years ago (Brandt, 1984). Trees and shrubs have been retained and planted on agricultural landscapes (Asfaw and Nigatu, 1995; Kanshie, 2002). The historical development of our study agroforestry sites is related to the domestication of natural forest landscapes and intensification to agricultural lands (Negash and Achalu, 2008).

Originally, the sites were dominated by mid-altitude species, such as *Syzygium guineense, Pod carpus falcatus, Millettia ferruginea, Cordia africana, Croton macrostachyus, Aningeria adolfi-friederici* and *Erythrina* spp (Asfaw, 2003).

Despite of its vital role for biodiversity conservation of agroforestry and forest patches in tropical country, in Ethiopia the contribution of agroforests and forest patches on biodiversity conservation aspects has less emphasis and documentation (Negash et al., 2012b).

Therefore, the aim of the present study was to assess the status of woody species diversity in natural forest patches and adjacent Enset-Coffee based agroforestry (ECAF) with particular emphasis on their contribution to biodiversity conservation in the Midland of Sidama zone, Ethiopia.

MATERIALS AND METHODS

Study area

The two study sites, Wonsho and Shebedino district (here after woreda) were situated in Sidama Zone of Ethiopia (7°00'–7°06' N and 38°-34' E 38°_37' E) of southern Nations, Nationalities and regional state (Figure 1).

The topography of the districts is generally characterized by hilly (60%), flat (15%) and mountains (25%) and the elevation ranges from 1500 m to 3027 m.a.s.l (Asfaw, 2003).

The soils at the study sites are mainly classified as Nitosols (Asfaw, 2003). The average annual rainfall of Shebedino woreda is 1300-1500 mm and temperature is between 18-25°C (Negassa, 2005). Thirty three percent of the Woreda is classified as Dega (> 2300 m.a.s.l.) and the remaining 67% is Weina-dega(1500 – 2300 m.a.s.l)

The mean annual temperature and rainfall of Wonsho woreda range from 20-25°C and 1200 - 1600 mm, respectively (Negassa, 2005). This study area is largely found in the agro climatic zone of Weina-Dega (59%) and Dega (41%).

Method of data collection

Site selection

The two sites (Wonsho and Shebedino) were selected based on the presence of natural forest patches and intensive practices of ECAF. Those forest patches are surrounded by ECAF and settlements. At each site, two kebele from Shebedino and one kebele from Wonsho having extensive agroforestry practices and the presence of forest patches were purposively selected. Hence, two of the natural forest patches namely “Arossa", "Akako" were selected from Garagalo Kebele, and Telamo Kebele in Shebedino woreda, respectively. "Abo" forest patch from Bokaso Kebele in Wonsho woreda was selected. The native forest patches are separated by agroforests that have been practiced for long period of time, and settlements. The average distance between the three patch forests is 15 km. Arosa, Akako and Abo natural forest patches are about 2.12 ha, 1.8 ha and 32.5 ha areas, respectively.

Sampling techniques

In Sidama zone, south Ethiopia, agroforestry have been practiced for long period of time reserving the original *podo- coridia* dominant natural forest. After clearing of the forests for purpose of settlements, monocropping and agroforestry practices, the three patch forest has been left for traditional religious purposes. The three patch forests have similar ages and homogenous habitat natures, because they are previously considered as one natural forest. Similarly, the practices of ECAF surrounding the forest patches also have homogenous nature which uses Enset as the staple food and main crop in the areas. Because of this, systematic sampling method was employed for this study. The sampling procedures focused on identification of area having forest patches and the orientation of each forest patches and adjacent ECAF (Figure 2). Each forest was divided into four parts where one line run through the center from east to west and the other running from south to north (Figure 2). In order to locate quadrat for adjacent ECAF, the four transect lines was extended up to 2 km from

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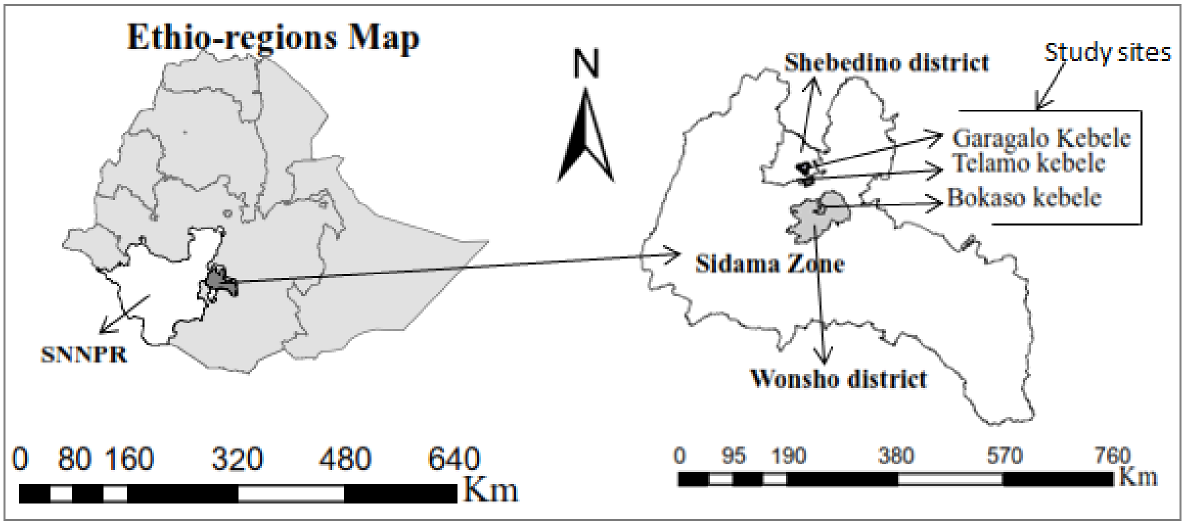

Figure 1. Map of study of sites in midland of Sidama**,** Southern Nations, Nationalities, and People Regional state (SNNPRs), Ethiopia.

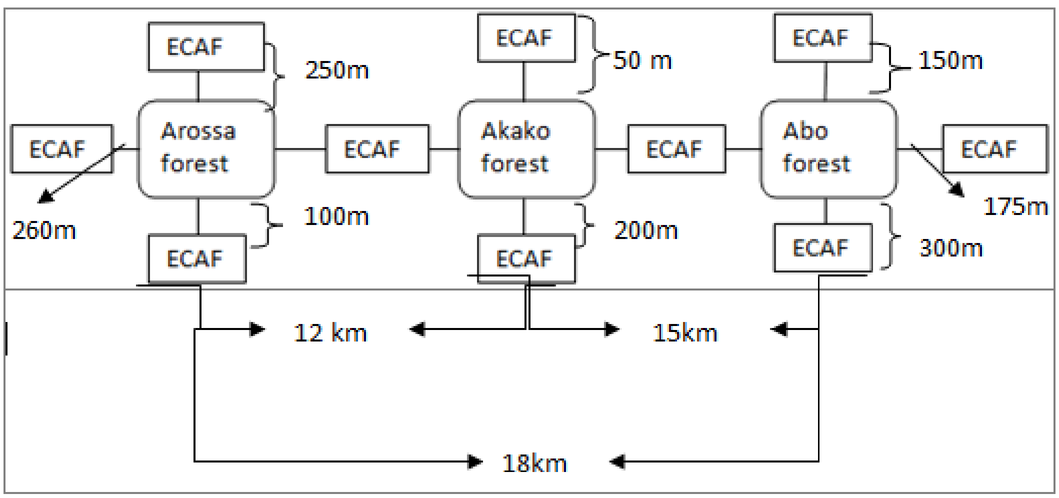

Figure 2. Layout of transect lines for woody species diversity and connectivity study between ECAF and each natural forest patch.

forest patches. On each line E-W and S-N, a serious of quadrats was laid at an interval of 0.5 km in boarder of each forest patch (Figure 2). Hence, 48 quadrats (16 quadrats in each kebele) were established for vegetation assessment for ECAF. To study similarity of woody species compositions managed in ECAF and in the three forest patches, three transect lines was established (Figure 3). On each transect line; four quadrats with intervals of 3 km between quadrat were laid out. A total of 48 quadrats (16 quadrats in each forest patch) were employed for woody species inventory between ECAF and each forest patch.

Sampling design and diversity inventory

For this study, a quadrat size of 20 x 20 m was employed for both ECAF and natural forest patches (Hernandez et al., 2004). Five sub-plots using ''X'' design within the main plots by 5 x 5 m and 2 x 2 m was laid for sapling/shrubs and seedling (<1cm diameter) assessment, respectively (Hernandez et al., 2004). All woody species ≥ 5cm in the main plots were identified and measured using a caliper at breast height (DBH, 1.3 m) (Mac Diken, 1997). Woody species diameters beyond caliper level were measured by measuring tape. Those woody species < 5 cm in sub plots were only identified and counting.

The woody species present in the study area was first identified by their local names in Sidamegna and scientific name was identified using Flora of Ethiopia and Eritrea (Edwards et al., 1995; Hedberg et al., 2004; Hedberg et al., 2006) and "Useful Trees and Shrubs for Ethiopia" (Bekele, 2007).

Data analysis

Woody species diversity and evenness indices in each ECAF and forest patches were calculated by using common alpha diversity indices (Magurran, 2004). Shannon diversity and equitability index

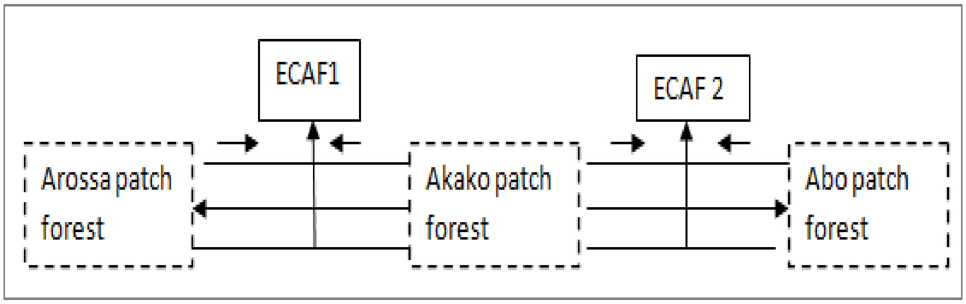

Figure 3. Layout of transect lines for woody species similarity study between the three forest patch and ECAF.ECAF1= Enset-coffee based agroforestry found between Arossa and Akako patch forest; ECAF2=Enset-coffee based agroforestry found between Akako and Abo patch forest.

place most weight on the rare species in the sample ((Magurran, 2004). In order to include the most abundant species, Simpson's diversity index was used. Simpson diversity index gives relatively little weight to the rare species and more weight to the most abundant species. These indices indicate richness and evenness of species within a locality, but they do not indicate the identity of the species where it occurs. Hence, similarity/dissimilarity in composition of woody species among the study forest patches and agroforests was determined by computing Sorensen similarity index. This diversity index takes into account species richness and abundance (Magurran, 2004).

In order to identify the most ecologically importance woody species in study area, importance value index was calculated. The importance value index is a composite index based on the relative measures of species frequency, abundance and dominance (Kent and Coker, 1992). It indicates the significance of species in the system.

The effect of variation in terms of woody species diversity was tested using one way ANOVA and means difference between ECAF and forest patches were considered significant at $p < 0.05$ using least significance difference (LSD).

RESULTS

Floristic composition

A total of 75 woody species were recorded and categorized under 31 families, of which 43 species under 30 families were from the natural forest patches and the remaining 32 species under 21 families from ECAF (Appendix 1 and 2). Twenty two woody species were common to both the natural forest patches and ECAF. Euphorbiaceae and Rutaceae family had the most diverse each having seven and six species, respectively in natural forest patches. Both Myrsinaceae and Araliaceae families each having five species also contributes to the diversity of natural forest patches. Similarly, for ECAF, Euphorbiaceae, Papilioniaceae and Rutaceae families had the most diverse each having three species. The contributions of the remaining families for species richness in ECAF were Asteraceae, Boraginaceae, Cupressaceae, Lauraceae and Myrtaceae with two species. The proportion of indigenous woody species was higher (86.67%) than exotic (13.33%), (Appendix 1 and 2).

Variations were also observed in terms of the relative frequency (Figures 4 and 5). *Cordia africana* (96.7%), *Coffea arabica* (90%), *Millettia ferruginea* (83.3%), *Croton macrostachyus,* (66.7%) and *Persea americana* (63.3%) were the five most frequently found woody species in ECAF (n=48) (Figure 4). From the total 32 woody species, nine species had the lowest frequently found (3.33%) (Figure 4).

Afrocurpus falcatus woody species were 100% frequently found in the study natural forest patches *(n=48) (*Figure 5). *Bersama abyssinica* (96.7%), *Vernonia auriculifera* (83.3%) and *C. macrostachyus* (73.3%) were the other four most frequently found woody species. From the total 43 woody species, 15 species were the lowest frequently found across study natural forest patches (3.3%) (Figure 5).

Woody species diversity

Table 1 shows woody species richness of the each study site. In the natural forest patches, the highest numbers of woody species (richness) were recorded at Abo-Bokaso site and lowest number of species was recorded at Arossa-Garagalo (Table 1). In ECAF, the highest numbers of woody species were found at Akako-Telamo site and lowest number of species was recorded at Arossa-Garagalo (Table 1).

The woody species richness of natural forest patches were significantly ($p<0.05$) higher than ECAF (Table 2). Similarly, there was higher significant ($p<0.05$) variation of woody species abundance per plot in the natural forest patches.

The Shannon diversity index was greater in Abo-Bokaso natural forest patch, and its adjacent ECAF (Table 3). The least Shannon diversity index was recorded in Arossa-Garagalo in both land use type. Shannon evenness (92%) indicates that relatively highest homogeneity of woody species was found in Abo-Bokaso

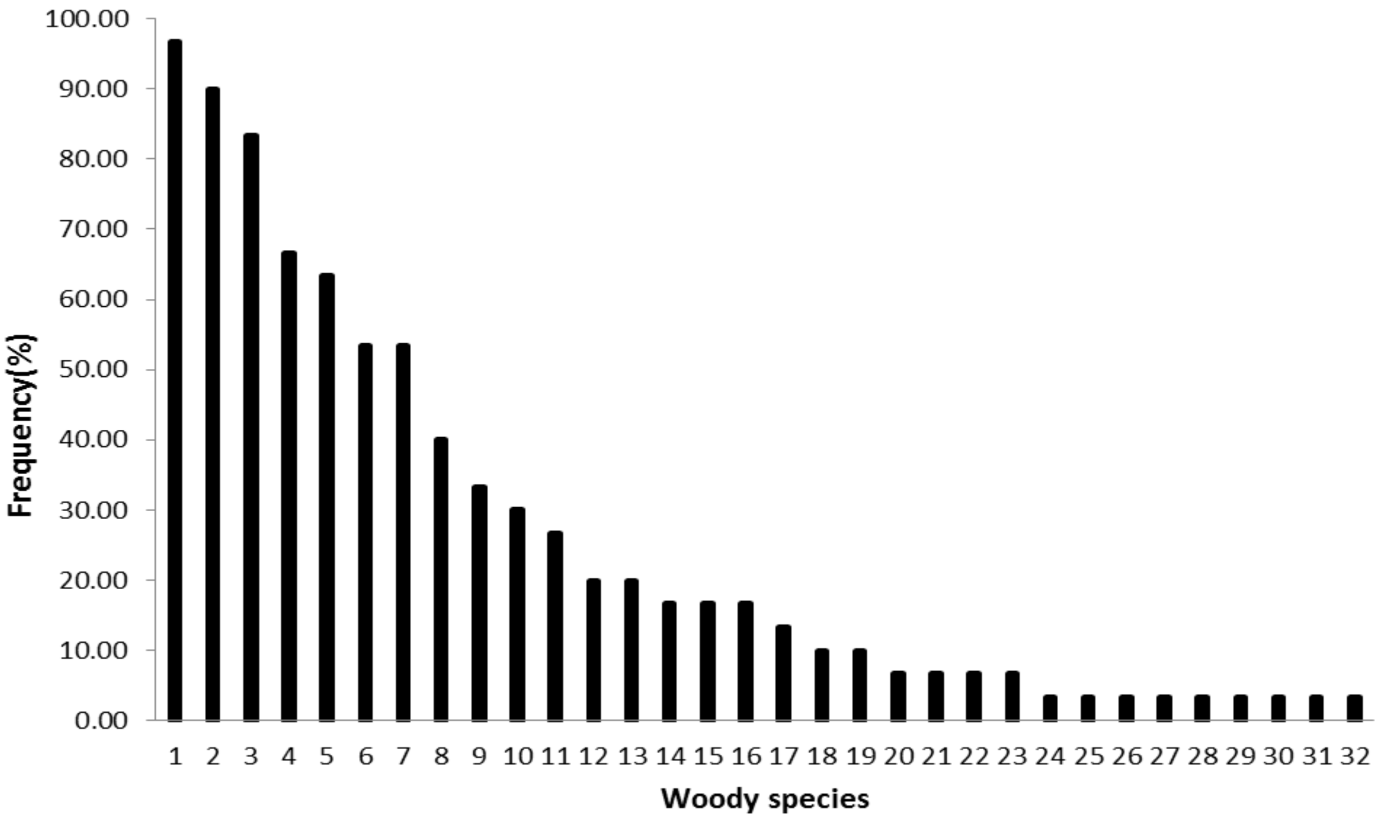

Figure 4. Overall frequency occurrences of woody species across the adjacent ECAF in the midland of Sidama zone, Ethiopia. 1 = *Cordia Africana; 2 = Coffea Arabica;* 3 = *Millettia ferruginea;* 4 = *Croton macrostachyus;* 5 = *Persea Americana;* 6 = *Afrocurpus falcatus;* 7 = *Vernonia auriculifera;* 8 = *Prunus Africana;* 9=*Calpurnia ourea;* 10 = *Fagaropsis angolensis;* 11 = *Bersama abyssinica;* 12= *Syzygium guineense;* 13= *Polyscias fulva;* 14 = *Erythrina brucei;* 15 = *Catha edulis;* 16 = *Maesa lanceolata;* 17 = *Brucea antidysentrica;* 18= *Euphorbia abyssinica;* 19 = *Ficus sur;* 20 = *Casimiora edulis;* 21 = *Ehretia cymosa;* 22 = *Ocotea kenyensis ;* 23 = *Diphasia dainelli;* 24 = *Ricinus communis;* 25 = *Eucalyptus globules;* 26 = *Rhamnus prionoides;* 27 = *Albizia gummifera;* 28 = *Grevillea robusta;* 29=*Cupressus lusitanica;* 30 = *Celtis Africana;* 31 = *Juniperus procera;* 32 = *Vernonia amygdalina.*

natural forest patch compared to other natural forest patches (Table 3). Similarly, the highest evenly distributions of woody species in adjacent ECAF were found in Arossa- Garagalo site (Table 3).

Inland use type comparison, Shannon and Simpson diversity indices of woody species from natural forest patches were significantly ($p < 0.05$) higher than the ones from ECAF (Table 4). However, no significant difference ($P < 0.05$) was observed between the two lands use types in terms of Shannon evenness.

Similarity in woody species compositions of the study land use types

Person's correlation indicated that similarity of woody species of ECAF from each natural forest patch was negatively correlated with distances (Figure 6). This means that when distance increase from the natural forest patch, the similarity of woody species composition between ECAF and natural forest patches was decreased.

Based on presence-absence of woody species in the sampled plot, more than half similarities were existed between overall natural forest patches and ECAF (Table 5). In comparison for each forest patches and their adjacent ECAF, the highest similarity was observed between Arossa-Garagalo natural forest patch and its adjacent ECAF. The least similarity was found between Akako-Telamo natural forest patch and its adjacent ECAF.

The similarity of woody species composition between each three forest patch and adjacent ECAF can be also explained by the presence-absence of species in the land use types (Table 6). Highest similarity of woody species was recorded between Arossa-Garagalo natural forest patch and Akako-Telamo natural forest patch. The Arossa-Garagalo natural forest patch and Abo-Bokaso natural forest patch showed slightly lower similarity. ECAF1 had higher similarity with the nearest Arossa-Garagalo and Akako forest patch, and least similarity with Abo patch. However, ECAF2 was higher similar to Arossa-Garagalo and Akako-Telamo natural forest patch

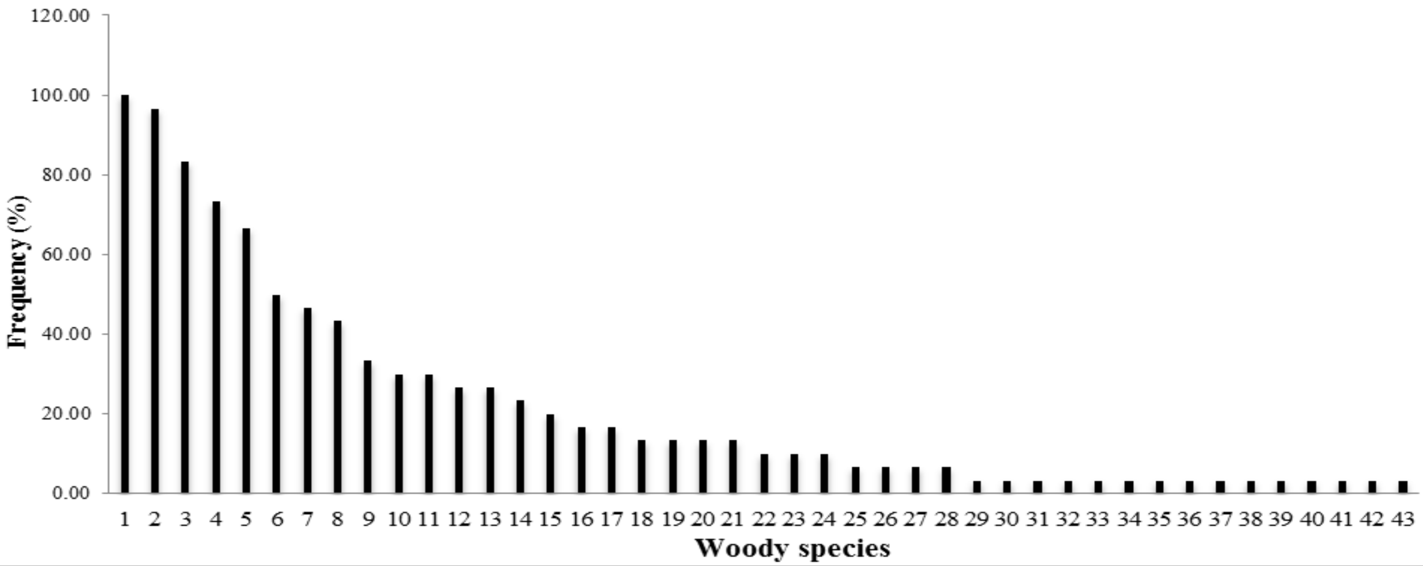

Figure 5.Overall frequency occurrences of woody species across the study natural forest patches in the midland of Sidama zone, Ethiopia.
1 = *Afrocurpus falcatus;* 2 = *Bersama abyssinica;* 3 = *Vernonia auriculifera;* 4 = *Croton macrostachyus;* 5= *Brucea antidysentrica;* 6 = *Calpurnia ourea;* 7 = *Maesa lanceolata;* 8 = *Euphorbia abyssinica;* 9 = *Celtis africana;* 10 = *Acokanthera schimperi;* 11= *Justicia schimperiana; 12* = *Fagaropsis angolensis;* 13 = *Polyscias fulva;* 14 = *Ehretia cymosa;* 15 = *Prunus africana;* 16 = *Diphasia dainelli;* 17 = *Olea africana;* 18 = *Syzygium guineense;* 19 = *Celtis kraussiana;* 20 = *Cordia africana;* 21 = *Delonix regia; 22 = Ekbergia capensis;* 23 = *Ricinus communis;* 24 =*Teclea nobilis;* 25 = *Maytenus arbutifolia;* 26 = *Macaranga kilimands;* 27 = *Pouteria adolfi-friedericii;* 28 = *Spathodea nilotica;* 29 = *Juniperus procera;* 30 =*Cupressus lusitanica; 31* = *Afrocarpus gracilor;* 32 = *Galiniera saxifrage;* 33 = *Hypericum revoltum;* 34=*Ficus vasta;* 35 = *Phytolaca deodecandra;* 36= *Prunus persica;* 37 =*Albizia gummifera;* 38 = *Agavae sisaliyana;* 39 = *Arundinaria alpina;* 40 = *Ocotea kenyensis;* 41 = *Ficus sur;*42 = *Dodonaea viscosa;* 43 = *Lepidotrichilia volkensii.*

Table 1. Woody species richness in each natural forest patch and adjacent ECAF in the midland of Sidama zone, Ethiopia.

Forest/site name	Number of species (richness) in	
	Patch forest	ECAF
Akako-Telamo	20	27
Arossa-Garagalo	17	15
Abo- Bokaso	31	17
Overall richness	43	32

Table 2. Mean (±std) woody species richness and abundance per plot of the two land use types.

Land use type	Richness	Abundance
	Mean(±std)	Mean(±std)
ECAF	8.2^{a}±0.413	79.3^{a}±7.291
Natural forest Patches	9.6^{b}±0.188	128.5^{b}±9.281
Overall mean	8.9±3.099	103.9±16.551

Means followed by a different superscript (a, b) are significantly different at LSD (p< 0.05.

Table 3. Woody species diversity in each vegetation patches and adjacent ECAF in the midland of Sidama zone, Ethiopia.

Forest/site name	Woody species diversity in					
	Patch forest			ECAF		
	Shannon	Simpson	Evenness	Shannon	Simpson	Evenness
Akako-Telamo	2.70	0.96	0.86	2.31	0.96	0.86
Arossa-Garagalo	2.61	0.98	0.80	2.21	0.97	0.89
Abo- Bokaso	2.75	0.9	0.92	2.41	0.96	0.61

Table 4. Mean (±std) woody species diversity index of Shannon, Evenness and Simpson per plot of the two land use type.

Land use type	Shannon	Simpson	Evenness
	Mean (±std)	Mean (±std)	Mean (±std
ECAF	1.55^{a} ±0.033	0.71^{a}±0.017	0.76^{a} ±0.02
Natural forest Patches	1.81^{b}±0.054	0.79^{b}±0.001	0.8^{a} ±0.01
Overall mean	1.68±0.058	0.75±0.005	0.78±0.02

Means followed by a different superscript (a, b) are significantly different at LSD (p< 0.05).

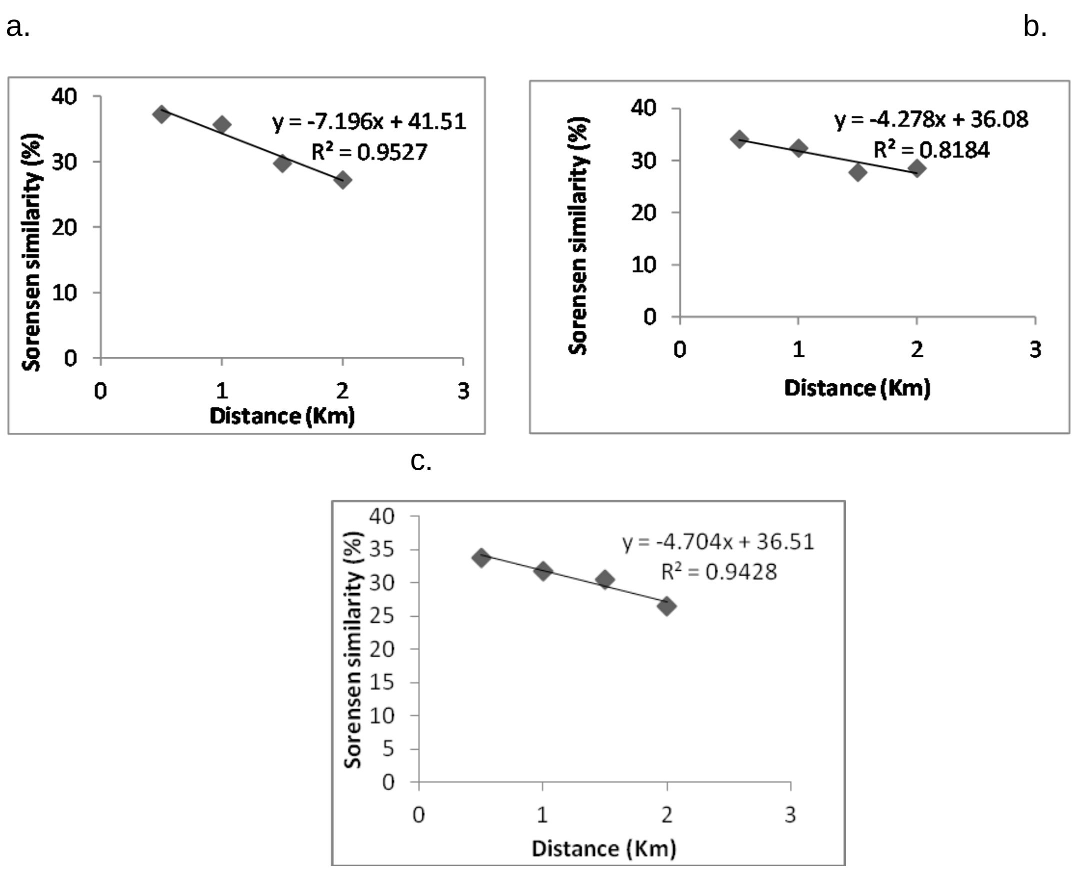

Figure 6. Correlation between the Sorensen similarity (%) of woody species and distance of ECAF from each natural forest patch. **a.** At Akako natural patch forest; **b.** At Arossa natural forest patch; **c.** At Abo natural forest patch.

Table 5. Sorensen's similarity index of woody species between each vegetation patches and adjacent ECAF in the midland of Sidama zone, Ethiopia .

Forest/site name	Sorensen's similarity index (%) With adjacent ECAF
Arossa-Garagalo	56.25
Akako-Telamo	48.89
Abo- Bokaso	50
Overall similarity of patch forests	58.67

Table 6. The mean Sorensen's similarity index of woody species between each vegetation patches and ECAF in the midland of Sidama zone, Ethiopia.

Land use/site name	Sorensen's similarity index (%) land use/site name				
	Arossa-Garagalo	ECAF1	Akako-Telamo	ECAF2	Abo-Bokaso
Arossa-Garagalo		46.4	54.1	46.6	41.7
ECAF1			47.9	55.4	32.34
Akako-Telamo				46.9	50.9
ECAF2					38.4
Abo-Bokaso					

ECAF1= Enset-coffee based agroforestry found between Arossa and Akako forest patch; ECAF2= Enset-coffee based agroforestry found between Akako and Abo forest patch.

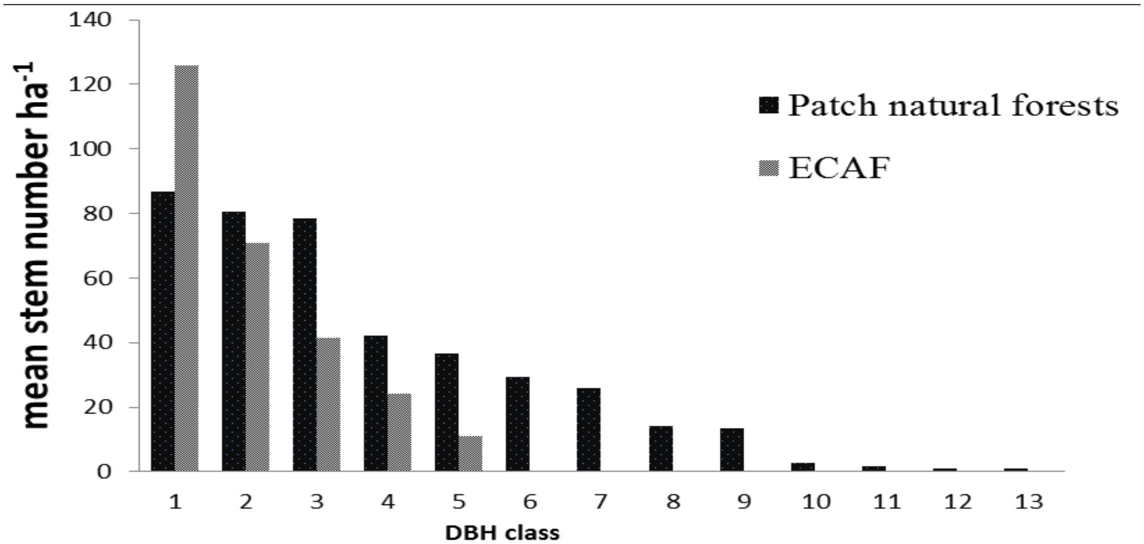

Figure 7. Cumulative frequency distributions of woody species by diameter class in overall Natural forest patches and ECAF in the midland of Sidama. Diameter class in cm **1**= 5-15, **2**= >15-25, **3**= >25-35, **4**= >35-45, **5**= >45-55, **6**= >55-65, **7**= >65-75, **8**= >75-85, **9**= >85-95, **10**= >95-105, **11**= >105-115, **12**= >115-125, **13**= >125.

and least similarity with the Abo-Bokaso forest patch. More than 50% of woody species similarity was found in ECAF1 and ECAF2.

The similarity of woody species composition in each forest patch and ECAF along transect distance was indicated in an Appendix 5. The highest similarity of woody species in ECAF was found near to the natural forest patches in all types of forest patch at referencing point (0.5 km) (Appendix 5).

Community structure of woody species

Community structure of woody species in the natural forest patches and ECAF in terms of mean numbers of

Table 7. The top five most IVI of woody species in a decreasing order in natural forest patches and ECAF in the midland of Sidama, Ethiopia.

Land use type	Scientific name	Important value index (IVI in %)
Natural forest patches	*Afrocurpus falcatus*	78.9
	Vernonia rueppllii	24.1
	Bersama abyssinica	22.2
	Calpurnia ourea	21.0
	Celtis africana	16.8
ECAF	*Coffea arabica*	65.8
	Cordia africana	47.5
	Millettia ferruginea	22.7
	Croton macrostachyus	19.3
	Persea americana	18.9

trees in diameter classes are presented in Figure 7.

Although the young individuals belonging to 5-15 cm DBH class were dominating in both land use systems, the number of stems (≥ 5cm DBH) were greater in natural forest patches than ECAF plots. In the natural forest patches, the 79% of the total tree density was distributed between 5 to 45 cm diameter classes. However, in ECAF, 72% of the total tree density was distributed between 5 and 25 cm. Generally, the cumulative diameter class distribution pattern was an inverted J-shape, which showed that the species frequency was highest in the lower diameter classes and decreased gradually towards the higher classes.

Importance value index of woody species

The importance value index (IVI) measures the overall importance of a species and gives an indication of the ecological success of a species in a particular area. The IVI of all woody species in each land use type was indicated in Appendix 3 and 4. The five most important woody species with the highest IVIs in the natural forest patches and ECAF in decreasing order is given in Table 7. *A. falcatus* followed by *V. rueppllii* was the highest IVI in natural forest patches, and *C. arabica* and *C. africana* was in the ECAF (Table 7).

DISCUSSION

Woody species composition and diversity

Our results indicate that for ECAF in the study sites, the total woody species richness number was comparatively lower than that recorded in enset-coffee-based agroforests (58 woody of species) and tree-cereal-based agroforestry systems (64 woody species) of the south-central and southern highlands of Ethiopia, respectively (Negash et al., 2012b; Asfaw, 2003). In previous studies (Asfaw 2003; Tolera et al., 2008), total number of all woody individuals vary, which might be due to the comparatively limited number of stems. For example, Gedeo multistrata agroforestry system is characterized by both horizontally and vertically densely packed agroforestry systems (Tesemma, 2007). ECAF at our study sites had four strata (Negash et al., 2012b). The variation may be ecological, demographic, farm size, the physical condition of the site and socioeconomic factors of the area. Variation in mean number of species richness and abundance was also shown among agroforest types. Farmers in enset-AF give more emphasis to managing and cultivating *E. ventricosum* with native woody species (Negash et al., 2012b). They practice thinning to create more space for production of *E. ventricosum*. Wider spacing of trees would allow more growth in tree diameter rather than in stem numbers in enset-AF.

The total woody species recorded in the natural forest patches was also comparable to earlier studies in Ghana (47) natural forests (Amoha, 2011), but higher than Tanzania (29) (Rocky and Mligo, 2012). Woody species richness and abundance in natural forest patches were significantly higher than ECAF is consistent with other study in India and Gahana (Amoha, 2011, Tynsong and Tiwari, 2011). High species richness and abundance could be due to relatively minimum disturbance by the people over a long period in forest patches, and species preferences in ECAF system.

The overall Shannon's diversity and evenness in study ECAF were 2.31 and 0.79 respectively. According to Kent and Coker (1992), the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5. In our study of ECAF and natural forest patches, the diversity indices and evenness were in line with the stated ranges. It was also comparable with the studies from north- western homegardens of Ethiopia (H'=3.34) (Mekonnin et al, 2014). However, it was comparatively higher than that was in enset-coffee-based agroforests (H'=1.07), Sidama homegardens, (H'= 1.44) of the south-central and southern highlands of Ethiopia, (respectively (Negash et al., 2012b; Abebe, 2005) but lower than homegarden of Meghalaya (H'=2.37) (Tynsong and Tiwari, 2010). The variation perhaps depends on differences in farmers' management intensity, and on environmental conditions. Farmers' shade intensity management includes species selection, setting spacing, pollarding, lopping and thinning (Negash et al., 2012b; Abebe, 2005).

Shannon's diversity index (2.61) in natural forest patches agrees with Harenna forest (H'=2.60), but higher than maji forest (H'=1.54) (Senbeta, 2006). Higher diversity index in natural forest patches than ECAF was comparable with Ghana natural forests and taungya agroforestry (Amoha, 2011). This could be the uniform distribution of species in natural forests, site characteristics and enriched by the farmers with economically important tree species that meet the needs of the local people in ECAF.

The frequent occurrence of the most valuable woody species was estimated to know the extent of species distribution in study areas. Our results also show that *C. Africana* (96.7%), *C. arabica* (90%) and *M. ferruginea* (83.3%) were the highest frequently occurring tree species in studies of ECAF. *M. ferruginea* in particular was the most abundant and frequent native species across all study ECAF sites. This is mainly due to the easy adaptability, propagation and management regime of the species (Negash et al., 2012b; Abebe, 2005). A study carried out in southern Ethiopia also showed that the Millettia tree increased the productivity of crops planted beneath it, due to frequent planting in and the in the border of the farm lands (Hailu et al., 2000). In addition, In ECAF, both *C. africana* and M. ferruginea recommended as coffee and enset shade. Similar studies were observed in southern and eastern Ethiopia (Teketay and Tegineh, 1991; Abebe, 2005; Negash et al., 2012b). The most frequently found of this species, particularly *M. ferruginea* and *C. arabica* only found in ECAF were due to the complimentary to agricultural crops and being provider of multiple benefits to the societies (Abebe, 2005).

The importance value index (IVI) rank species in a way as to give an indication on which species come out as important component of the on-farm trees (Munishi et al., 2008). It measures the overall importance of a species and gives an indication of the ecological success of a species in a particular area. The most important tree species which is the highest IVI recorded in ECAF system agrees with the study by Abebe (2005) that reported tree species with highest importance value indices.

The most important tree species in the natural forest patches were *A. falcatus*, *V. rueppllii*, *B. abyssinica*, *C. ourea* and *C. africana*. They are common and abundant because of their wide economic and ecological roles in the systems. The IVI values can also be used to prioritize species for conservation, and species with high IVI value need less conservation efforts, whereas, those having low IVI value need high conservation effort.

The overall community structure of the patch forests and ECAF can help understand the status of regeneration. Reverse J-shaped distributions indicated more or less a healthy or stable regeneration (Tesfaye et al., 2010; Worku et al., 2012). This means high numbers of individuals (juvenile/seedling) in the lower diameter classes but decreases towards the higher classes. The observation of juvenile/seedling phase of these woody species is an evidence of dynamics in managing biodiversity in the land uses.

Similarity of woody species and implication to agriculture landscape connectivity

Agroforest land use can provide potential sites for maintaining both species in agricultural landscapes. The increased incorporation of woody species in agroforestry land can reduce pressure on forests and protected conservation areas. The result of present study indicate that woody species recorded from ECAF constitutes larger proportion of indigenous species (84.6%), which may be a reflection of the conservation of biodiversity in the agricultural landscapes. Similar trend were observed by other scholars (Abebe, 2005) for 83% indigenous tree species. Asfaw (2003) reported about 68 to 80% indigenous tree species for different sites in the traditional agroforestry practices of Sidama, Ethiopia.

Our results also indicate that 58.67% of woody species composition similarity existed between natural forest patches and ECAF. Such overlap of woody species indicated that development of buffer zone agroforestry adjacent to the natural forest would help to provide different uses and services, which were being obtained from natural forest by the local community and thus bring down the dependency on the natural forests and take as conservation strategy for threatened forest resource (Worku, 2011; Kasolo & Temu, 2008). ECAF can also serve as gene pools for the eroding indigenous woody species. Many indigenous, rare woody species like Cordia africana, Croton macrostachys and Afrocarpus falcate conserved in ECAF because of their high multiple values. This finding was supported by Gebremariam et al. (2009); they reported that *C. africana* and *P. falcatus* are accounted as locally endangered species, and are not legally permitted to be felled in state and private forests, owing to their high exploitation in natural forests in Ethiopia. Agroforestry can also create habitat for wild animal species in landscape matrices surrounding forest conservation areas (Buck et al., 2004). Therefore, the integration of woody species in the homegardens adds plant and animal biodiversity into landscapes that might otherwise contain only monocultures of agricultural crops (Guo, 2000).

Conclusion

The ECAF and natural forest patches in our studies constitutes larger proportion of indigenous woody species which may be a reflection of the conservation of biodiversity in the agricultural landscapes. This is possibly due to farmers' management practice in maintaining more native trees for shading both coffee and enset particularly in ECAF. In addition, ECAF play a major role in the conservation of native woody species like *Syzygium guineense* and *Juniperus procea* which are endemic in Ethiopia, and the critically threated species like *Pouteria adolfi-friedericii* and *prunus Africana.* Our study shows that ECAF are also important for preserving the most economical value trees such as *C. africana, Croton macrostachys* and *Afrocarpus falcate* which uses as shade of coffee and enset.

Our study also indicated a higher similarity of woody species composition between ECAF and natural forest patches. This may reduce the dependency of local communities on forest patches due to ECAF and provides different uses and services which can be obtained from natural forest patches.

Conflict of Interests

The author(s) have not declared any conflict of interests.

ACKNOWLEDGEMENTS

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Appendix

Appendix 1. The botanical name of woody species in the overall natural forest patches in Shebedino and Wonsho district in the midland of Sidama zone, Ethiopia.

No.	*Botanical name*	Local name	Origin	Family
1.	*Acokanthera schimperi* (D.C., Oliv)	Qararu	Indigenous	Apocynaceae
2.	*Afrocurpus falcatus (*Thunb.)**	Dagucho	Indigenous	Podocarpaceae
3.	*Afrcarpus gracilor* (Oliv.& hiern)	Danishicho	Indigenous	Podocarpaceae
4.	*Agavae sisaliyana* (Perr)	Qacha	Exotic	Agavaceae
5.	*Albizia gummifera* (G.F.Gmel..C.A.Sm.)	Maticho	Indigenous	Mimosaceae
6.	*Arundinaria alpina* (K.Schum)	Lemicho	Indigenous	Bambusaceae
7.	*Bersama abyssinica* (Fres)	Xabaraco	Indigenous	Melianthaceae
8.	*Brucea antidysentrica* (J.F.Miller)	Haxawicho	Indigenous	Simaroubaceae
9.	*Calpurnia ourea (*Lam., benth)	Chekata	Indigenous	Papilioniaceae
10.	*Celtis africana (*Burm.F.)	Shisho	Indigenous	Ulmaceae
11.	*Celtis kraussiana* (Bernh)	sheshie	Indigenous	Ulmaceae
12.	*Cordia africana* (Lam)	Wadicho	Indigenous	Boraginaceae
13.	*Croton macrostachyus* (Hochst. Ex. Del.)	Macincho	Indigenous	Euphorbiaceae
14.	*Cupressus lusitanica* (Mill.)	Homme	Exotic	Cupressaceae
15.	*Delonix regia (*Bojer Ex Hook. Raf)	*yederdawa zafe	Exotic	Caesinalpiodeae
16.	*Diphasia dainelli* (Pichi-Sem.)	Lelcho	Indigenous	Rutaceae
17.	*Dodonaea viscosa* (L.F.)	Itancha	Indigenous	Sapindaceae
18.	*Ehretia cymosa* (Thonn.)	Gidincho	Indigenous	Boraginaceae
19.	*Ekbergia capensis* (Sparrman)	Oloncho	Indigenous	Meliaceae
20.	*Euphorbia abyssinica (*Gmel.)	Carricho	Indigenous	Euphorbiaceae

Appendix 1. Contd.

No.	***Botanical name***	**Local name**	**Origin**	**Family**
21.	*Fagaropsis angolensis (*Engl.Del.)	Goddicho	Indigenous	Rutaceae
22.	*Ficus sur (*Forssk.)	Oddako	Indigenous	Moraceae
23.	*Ficus vasta (*Forssk)	*Warka	Indigenous	Moraceae
24.	*Galiniera saxifrage* (E.Mey.Ex Benth)	Dongicho	Indigenous	Icacinaceae
25.	*Hypericum revoltum (*Vahl)	Garambicho	Indigenous	Hypericaceae
26.	*Juniperus procera* (Hochst.Ex. Endl.)	Honcho	Indigenous	Cupressaceae
27.	*Justicia schimperiana* (Hochst.ex Nees)	Cheketa	Indigenous	Acanthaceae
28.	*Lepidotrichilia volkensii (*Gurke, Leroy)	Tontoloma	Indigenous	Meliaceae
29.	*Macaranga kilimands* (Pax)	Felleco	Indigenous	Euphorbiaceae
30.	*Maesa lanceolata (*Forssk)	Gobacho	Indigenous	Myrsinaceae
31.	*Maytenus arbutifolia* (A.Rich,Wilczeck)	Cucco/atata	Indigenous	Celastraceae
32.	*Ocotea kenyensis (*Kosterm).	Shoecho	Indigenous	Lauraceae
33.	*Olea africana* (Mill*)*	Ejersu	Indigenous	Oleaceae
34.	*Phytolaca deodecandra* (L'Herit)	Haraje	Indigenous	Phytolacaceae
35.	*Polyscias fulva* (Hiern,Harms)	Kobree	Indigenous	Araliaceae
36.	*Pouteria adolfi -friedericii (*A..Chev,Aubrev & Pellegr)**	Dugucho	Indigenous	Sapotaceae
37.	*Prunus africana (*Hook.f. Kalkm)	Garbich	Indigenous	Rosaceae
38.	*Prunus persica (*L. Batsch*)*	Koke	Exotic	Rosaceae
39.	*Ricinus communis* (L.)	Qenbo	Indigenous	Euphorbiaceae
40.	*Syzygium guineense* (Wild.D.C*)*	Duwancho	Indigenous	Myrtaceae
41.	*Spathodea nilotica* (Seem)	*ychaka nebelbal	Exotic	Bignoniaceae
42.	*Teclea nobilis* (Del.)	Haddessa	Indigenous	Rutaceae
43.	*Vernonia auriculifera* (Hiern)	Rejicho	Indigenous	Asteraceae

*= Amharic name, all others Sidamegna name, **= the current name of *Podocarpus falcatus* and *Aningeria adolfi -friedericii.*

Appendix 2. The botanical names of woody species in enset-coffee based agroforestry in Shebedino and Wonsho district in the midland of Sidama zone, Ethiopia.

No.	***Botanical name***	**Local name**	**Origin**	**Family**
1.	*Afrocurpus falcatus (*Thunb.)	Dagucho	Indigenous	Podocarpaceae
2.	*Albizia gummifera (*G.F.Gmel.,.C.A.Sm.)	Maticho	Indigenous	Mimosaceae
3.	*Bersama abyssinica (*Fres.)	Xabaraco	Indigenous	Melianthaceae
4.	*Brucea antidysentrica* (J.F.Miller)	Haxawicho	Indigenous	Simaroubaceae
5.	*Calpurnia ourea* (Lam. benth)	Chekata	Indigenous	Papilioniaceae
6.	*Casimiora edulis* (La L,lave & Lex.)	Kasmire	Exotic	Rutaceae
7.	*Chata edulis* (Vahl. ,Forssk.ex Endl.)	Chate	Indigenous	Celastraceae
8.	*Celtis africana (*Burm.F.)	Shisho	Indigenous	Ulmaceae
9.	*Coffee arabica (*L.)	Bunu	Indigenous	Rubiaceae
10.	*Cordia africana* (Lam.)	Wadicho	Indigenous	Boraginaceae
11.	*Croton macrostachys (*Hochst. Ex Del.)	Macincho	Indigenous	Euphorbiaceae
12.	*Cupressus lusitanica* (Mill)	Homme	Exotic	Cupressaceae
13.	*Diphasia dainelli (*Pichi-Sem*.)*	Lelcho	Indigenous	Rutaceae
14.	*Ehretia cymosa (*T.honn)	Gidincho	Indigenous	Boraginaceae
15.	*Erythrina brucei* (schweinf)	Wellako	Indigenous	Papilonaceae
16.	*Eucalyptus globulus (*Labill.)	Waju arzafe	Exotic	Myrtaceae
17.	*Euphorbia abyssinica (*Gmel.)	Carricho	Indigenous	Euphorbiaceae
18.	*Fagaropsis angolensis (*Engl., Del.)	Goddicho	Indigenous	Rutaceae
19.	*Ficus sur (*Forssk.)	Oddako	Indigenous	Moraceae
20.	*Grevillea robusta (*A.Cunn.Ex.R.Br.)	Geravela	Exotic	Proteaceae

Appendix 2. Contd.

No.	***Botanical name***	**Local name**	**Origin**	**Family**
21.	*Juniperus procera (*Hochst.Ex. Endl.)	Honcho	Indigenous	Cupressaceae
22.	*Maesa lanceolata* (Forssk)	Gobacho	Indigenous	Myrsinaceae
23.	*Millettia ferruginea* (Hochyst, Baker)	Hengedicho	Indigenous	Papilionoideae
24.	*Ocotea kenyensis* (Kosterm)	Shoecho	Indigenous	Lauraceae
25.	*Persea americana* (Mill)	Abukato	Exotic	Lauraceae
26.	*Polyscias fulva* (Hiern, Harms)	Kobree	Indigenous	Araliaceae
27.	*Prunus africana* (Hook.f., Kalkm)	Garbicho	Indigenous	Rosaceae
28.	*Rhamnus prionoides* (L.'Herit.)	Taddo	Indigenous	Rhamnaceae
29.	*Ricinus communis* (L)	Qenbo	Indigenous	Euphorbiaceae
30.	*Syzygium guineense (*Wild., DC.)	Duwancho	Indigenous	Myrtaceae
31.	*Vernonia amygdalina* (Del.)	Hecho	Indigenous	Asteraceae
32.	*Vernonia auriculifera* (Hiern)	Rejicho	Indigenous	Asteraceae

Appendix 3. List of Frequency (FR), Abundance (AD), Relative frequency (RF), Relative abundance (RA), Relative dominance (RD) and Importance Value Indices (IVI) of woody species in the overall study natural forest patches.

No.	Botanical name	Frequency	Abundance	RD%	RA%	RF%	IVI%
1.	*Acokanthera schimperi*	9	143	0.00	3.83	3.18	7.01
2	*Afrocurpus falcatus*	30	675	50.23	18.06	10.60	78.89
3.	*Afrocarpus gracilor*	1	4	0.00	0.11	0.35	0.46
4.	*Agavae sisaliyana*	1	8	0.01	0.21	0.35	0.58
5.	*Albizzia gummifera*	1	10	0.00	0.27	0.35	0.62
6.	*Arundinaria alpina*	1	5	0.00	0.13	0.35	0.49
7.	*Bersama abyssinica*	29	398	1.29	10.65	10.25	22.19
8.	*Brucea antidysentrica*	20	304	0.00	8.13	7.07	15.20
9.	*Calpurnia ourea*	15	575	0.33	15.39	5.30	21.02
10.	*Celtis africana*	10	88	10.92	2.35	3.53	16.80
11.	*Celtis kraussiana*	4	43	0.00	1.15	1.41	2.56
12.	*Cordia africana*	4	16	0.44	0.43	1.41	2.28
13.	*Croton macrostachys*	22	126	5.03	3.37	7.77	16.18
14.	*Cupressus lusitanica*	1	2	0.00	0.05	0.35	0.41
15.	*Delonix regia*	4	36	0.36	0.96	1.41	2.73
16.	*Diphasia dainelli*	5	15	0.36	0.40	1.77	2.53
17.	*Dodonaea viscosa*	1	1	0.00	0.03	0.35	0.38
18.	*Ehretia cymosa*	7	12	0.32	0.32	2.47	3.11
19.	*Ekbergia capensis*	3	6	0.00	0.16	1.06	1.22
20.	*Euphorbia abyssinica*	13	35	4.76	0.94	4.59	10.29
21.	*Fagaropsis angolensis*	8	71	5.58	1.90	2.83	10.31
22.	*Ficus sur*	1	2	0.38	0.05	0.35	0.79
23.	*Ficus vasta*	1	12	0.00	0.32	0.35	0.67
24.	*Galiniera saxifrage*	1	6	0.45	0.16	0.35	0.96
25.	*Hypericum revoltum*	1	2	0.47	0.05	0.35	0.87
26.	*Juniperus procera*	1	2	0.00	0.05	0.35	0.41
27.	*Justicia schimperiana*	9	297	0.00	7.95	3.18	11.13
28.	*Lepidotrichilia volkensii*	1	1	0.00	0.03	0.35	0.38
29.	*Macaranga kilimands*	2	15	0.06	0.40	0.71	1.17
30.	*Maesa lanceolata*	14	54	2.59	1.45	4.95	8.98
31.	*Maytenus arbutifolia*	2	13	0.00	0.35	0.71	1.05

Appendix 3. Contd.

No.	Botanical name	Frequency	Abundance	RD%	RA%	RF%	IVI%
32.	*Ocotea kenyensis*	1	7	0.00	0.19	0.35	0.54
33.	*Olea africana*	5	24	0.00	0.64	1.77	2.41
34.	*Phytolaca deodecandra*	1	15	0.58	0.40	0.35	1.33
35.	*Polyscias fulva*	8	18	2.09	0.48	2.83	5.40
36.	*Pouteria adolfi -friedericii*	2	5	5.99	0.13	0.71	6.83
37.	*Prunus africana*	6	6	0.94	0.16	2.12	3.22
38.	*Prunus persica*	1	2	0.01	0.05	0.35	0.42
39.	*Ricinus communis*	3	56	0.00	1.50	1.06	2.56
40.	*Syzygium guineense*	4	11	5.07	0.29	1.41	6.77
41.	*Spathodea nilotica*	2	30	1.47	0.80	0.71	2.98
42.	*Teclea nobilis*	3	28	0.00	0.75	1.06	1.81
43.	*Vernonia auriculifera*	25	555	0.29	14.93	8.83	24.06

Appendix 4. List of frequency (FR), abundance (AD), relative frequency (RF), relative abundance (RA), relative dominance (RD) and Importance value Indices (IVI) of woody species in the ECAF in the midland of Sidama.

No.	Botanical name	Abundance	Frequency	RD %	RA%	RF%	IVI %
1.	*Afrocurpus falcatus*	11	12.00	5.61	0.45	4.90	10.96
2.	*Albizia gummifera*	1	1.00	0.11	0.03	0.41	0.55
3.	*Bersama abyssinica*	28	8.00	0.63	1.18	3.27	5.08
4.	*Brucea antidysentrica*	13	4.00	0.00	0.52	1.63	2.15
5.	*Calpurnia ourea*	69	10.00	0.00	2.88	4.08	6.97
6.	*Casimiora edulis*	5	2.00	0.00	0.21	0.82	1.02
7.	*Catha edulis*	142	5.00	0.00	5.91	2.04	7.95
8.	*Celtis africana*	4	1.00	0.31	0.17	0.41	0.89
9.	*Coffee arabica*	1267	27.00	1.05	53.75	11.02	65.83
10.	*Cordia africana*	220	29.00	26.45	9.17	11.84	47.46
11.	*Croton macrostachys*	53	20.00	8.90	2.19	8.16	19.25
12.	*Cupressus lusitanica*	3	1.00	0.00	0.10	0.41	0.51
13.	*Diphasia dainelli*	9	5.00	4.30	0.38	2.04	6.73
14.	*Ehretia cymosa*	1	1.00	0.04	0.03	0.41	0.48
15.	*Erythrina brucei*	3	3.00	1.52	0.14	1.22	2.88
16.	*Eucalyptus globulus*	4	3.00	4.41	0.17	1.22	5.80
17.	*Euphorbia abyssinica*	7	2.00	0.00	0.28	0.82	1.09
18.	*Fagaropsis angolensis*	32	9.00	1.02	1.32	3.67	6.01
19.	*Ficus sur*	7	5.00	3.03	0.28	2.04	5.35
20.	*Grevillea robusta*	2	1.00	0.00	0.07	0.41	0.48
21.	*Juniperus procera*	2	2.00	0.19	0.07	0.82	1.07
22.	*Maesa lanceolata*	67	1.00	0.59	2.78	0.41	3.78
23.	*Milletia ferruginea*	144	25.00	6.49	6.01	10.20	22.71
24.	*Ocotea kenyensis*	75	19.00	8.05	3.13	7.76	18.93
25.	*Persea americana*	73	16.00	0.00	3.06	6.53	9.59
26.	*Polyscias fulva*	1	1.00	0.00	0.03	0.41	0.44
27.	*Prunus africana*	1	1.00	0.01	0.03	0.41	0.46
28.	*Rhamnus prionoides*	4	2.00	0.10	0.17	0.82	1.09
29.	*Ricinus communis*	15	6.00	4.93	0.63	2.45	8.00
30.	*Syzygium guineense*	7	6.00	5.40	0.28	2.45	8.13
31.	*Vernonia amygdalina*	1	1.00	0.09	0.03	0.41	0.54
32.	*Vernonia auriculifera*	108	16.00	0.49	4.52	6.53	11.53

Appendix 5. The mean Sorensen's similarity index (%) of woody species at each natural forest patch and between ECAF in the midland of Sidama zone, Ethiopia.

	Sorensen's similarity index (%) of woody species																		
		Enset-coffee based agroforestry(ECAF1)									**Enset-coffee based agroforestry(ECAF2)**								
	Arossa F	**A1**	**A2**	**A3**	**A4**	**B5**	**B6**	**B7**	**B8**	**Akako.F**	**B9**	**B10**	**B11**	**B12**	**C13**	**C14**	**C15**	**C16**	**Abo.F**
Arossa forest		57.1	46.2	48.0	44.4	55.2	44.4	37.0	38.5	54.1	41.7	46.2	46.2	48.3	40.0	51.6	51.9	46.7	41.7
A1 (at 0.5km)from Arossa			66.7	48.0	72.7	91.7	54.5	45.5	57.1	56.3	52.6	66.7	76.2	75.0	64.0	69.2	81.8	64.0	37.2
A2 (at 3 km)from Arossa				47.1	52.6	66.7	52.6	21.1	77.8	50.0	25.0	55.6	44.4	57.1	45.5	52.2	42.1	45.5	35.0
A3(at 6km) from Arossa					55.6	70.0	55.6	33.3	47.1	35.7	53.3	58.8	70.6	60.0	57.1	72.7	66.7	76.2	30.8
A4 (at 9km) from Arossa						63.6	40.0	20.0	31.6	42.9	23.5	42.1	52.6	72.7	52.2	66.7	60.0	52.2	29.3
B5 (at 9km)from Akako							63.6	45.5	57.1	53.3	52.6	66.7	66.7	75.0	72.0	69.2	72.7	72.0	27.9
B6(at 6km) from Akako								42.9	52.6	50.0	35.3	73.7	63.2	37.0	60.9	50.0	70.0	63.6	34.1
B7(at 3km) from Akako									31.6	48.6	58.8	42.1	42.1	36.4	34.8	33.3	40.0	36.4	24.4
B8(at 0.5km) from Akako										46.7	33.3	44.4	44.4	57.1	45.5	52.2	47.1	45.5	40.0
Akako forest											56.3	55.2	41.4	29.6	42.4	52.9	46.7	48.5	51.0
B9(0.5km) from Akako												35.3	50.0	42.1	50.0	47.6	58.8	57.1	26.3
B10(at 3km)from Akako													55.6	57.1	54.5	43.5	63.2	54.5	30.0
B11(at 6km) from Akako														66.7	63.6	69.6	73.7	63.6	35.0
B12(at 9km) from Akako															56.0	69.2	63.6	56.0	37.2
C13(at 9km) from Abo																81.5	78.3	76.9	45.5
C14(at 6km) from Abo																	78.3	81.5	39.0
C15(at 3km) from Abo																		81.8	40.9
C16(0.5km)from Abo																			53.3
Abo forest																			

A1, A2………………C16 stands for number of quadrats; A1-----A4 quadrats has taken from Arossa patch forest towards Akako patch forest in ECAF1 land use; B8-----B5 quadrats have taken from Akako patch forest towards Arossa forest in ECAF1 land use; B9---B12 quadrats has taken from Akako patch forest towards Abo patch forest in ECAF2 land use. C16—C13 quadrats have taken from Abo patch forest towards Akako patch forest in ECAF2 land use. Sorensen's similarity of woody species at each forest and quadrats taken from ECAF land use were calculated.

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Water quality assessment of Labo and Clarin Rivers in Misamis Occidental, Philippines

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Labo and Clarin rivers are very important to many communities in Misamis Occidental, Philippines. Hundreds of people living near the two rivers depend on these waters for domestic and industrial purposes. This study was conducted to assess the water quality of two major river systems, Clarin and Labo rivers in Misamis Occidental, Philippines. Physico-chemical and biological parameters were assessed in three different sampling sites in each river. Results showed that dissolved oxygen, biological oxygen demand, total dissolved solids, nitrate and phosphate along the forest and agro forest sampling sites were at levels that fall within the standards set by the Department of Environment and Natural Resources (DENR) in the Philippines. However, the sampling station in Labo River located along the agricultural area showed values that are non-compliant with the DENR standard. The water temperature and pH range in sampling stations along the forest were within the tolerable range that will not cause stress to the aquatic organisms. Bacteriological analysis showed that all sampling stations were positive for coliforms (*Enterobacter aerogenes* and *Escherichia coli*). The sampling stations along the agroforest and agricultural areas had high total fecal coliform load. Results indicate the need to have proper environmental management program in Clarin and Labo rivers.

Key words: Aquatic, bacteriological, coliforms, physico-chemical, river systems.

INTRODUCTION

Rivers are natural flowing watercourses which show tremendous variation through time and space, and identified as very important ecosystem of the inland waters group (Hebert and Kundell, 2011). The rivers are vital carriers of water and nutrients. They are critical components of the hydrologic cycle, provide habitat, nourishments and means of transportation to countless organisms (Johansson et al., 1996; Ling et al., 2012). However, ecological imbalance due to widespread pollution, continuous activities and natural phenomena (Carr and Neary, 2006; Vorosmarty et al., 2010) caused the change of the water quality in rivers.

Water quality affects the productivity, biodiversity and complexity of the aquatic ecosystem (Pejman et al., 2009; Martinez and Galera, 2011). Changes in water quality may lead to degradation of ecosystem services (Dodds and Oakes, 2008) and loss of biological diversity. Water quality is determined by comparing the physical, chemical and

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biological characteristics of a water sample with water quality guidelines or standards (Carr and Neary, 2006; Pepa et al., 2011; Pathak, 2012; Gamedze et al., 2012). Several important parameters which include temperature, biological oxygen demand, dissolved oxygen, chlorides, pH, phosphorus, nitrate/nitrite/nitrogen and presence of fecal coliform can be used to assess the condition of rivers (Martinez and Galera, 2011; Jayalakshmi et al., 2011; Alam et al., 2007; Ayebo et al., 2006).

Threats to water quality can be both natural and human-related activity sources. Human-related activity sources which are considered the leading cause of water quality problems include agricultural and urban runoff, improper waste disposal and faulty septic systems (Shrestha and Kazama, 2006; Brown and Froemke, 2012; Haileselasie and Teferi, 2012).

Climate change is considered as current and biggest survival issue globally (Alvarez, 2010). According to Palmer (2007), major rivers worldwide will experience dramatic changes in flow due to continous damming and development. Through this changes, serious problems such as floods and droughts are expected to happen. Proactive restoration, rehabilitation and management actions are recommended to enhance the resilience of riverine ecosystems and minimize the impacts of climate change.

In the province of Misamis Occidental, studies in Layawan River of Oroquieta City and Langaran River in Plaridel showed that these rivers are relatively healthy (Palao et al., 2013; Roxas et al., 2005). However, no studies were conducted in Labo and Clarin Rivers although considered to be the most threatened rivers due to land conversion, cultivation and development along some parts of the rivers. Assessing the quality of the rivers is very important considering the fact that these rivers are the sources of water that provide the domestic, commercial and agricultural needs of the many residents of Misamis Occidental. Some portions of the rivers are under continuous tremendous pressure of human-related activities that have altered the physico-chemical status and threatened the aquatic organisms affecting the local residents in the area and in the lowlands. This study on the water quality of Labo and Clarin rivers aimed to provide the needed information on water quality based on physicochemical and bacteriological analysis.

MATERIALS AND METHODS

Study area

Misamis Occidental is a province located within Region X on the island of Mindanao. It covers 14 municipalites and three cities. It is bounded on the northeast by the Mindanao Sea, east by the Iligan Bay, southeast by the Panguil Bay, and the west by the Zamboanga del Norte and Sur. In this province, there are five major river systems including Labo and Clarin rivers. Labo river is strategically located within geographical coordinates of 123°49'8" to 123° 51' 52" east longitude and 8°10'31" to 8° 11' 32" north latitude. It is a natural boundary between Tangub City and Ozamiz City. Clarin river is located at the southern side of Misamis Occidental and strategically located within geographical coordinates 123° 37’ 30” to 123° 13’ 10” east longitude and 8° 7’30” to 8° 13’10” north latitude. It is the natural boundary between the municipality of Clarin and the city of Ozamiz, Misamis Occidental (Figure 1).

Sampling sites

Field sampling was conducted in Clarin and Labo Rivers in October 2010 and May 2011 to represent the wet and dry seasons, respectively. Three sampling sites were established in each river. Sampling site 1 was the portion of the river located along the forest area. Sampling site 2 was the part of the river along the agroforest area , while the third sampling site was the part of the river along the agricultural area. In each sampling site, three sampling stations were chosen. Each sampling station was further subdivided into three sampling points: right, middle and left portions of the river.

Sample collection

Water samples were collected from each sampling site using cleaned polyethylene bottles for physico-chemical analysis and 100-mL sterile bottles for microbial analysis. Each bottle was rinsed with the sample before the final sample collection. All sample bottles were tightly closed, properly labeled and placed in insulated cooler box with ice and immediately brought to the laboratory for analysis. If immediate analysis is not possible, water samples were stored at 4°C until processing and analysis.

Physico-chemical analysis

Physico-chemical parameters were determined following the Standard Methods for the Examination of Water and Wastewater American Public Health Association (APHA, 2005). Temperature, pH and dissolved oxygen (DO) were determined *in situ.* Water temperature was measured using the mercury-in-glass thermometer calibrated from 0-100°C. The pH and dissolved oxygen concentration were determined using the digital pH meter and membrane electrode probe, respectively.

Biological oxygen demand (BOD) was obtained using Winkler’s method. Turbidity was determined with the use of turbidity meter. The total dissolved solids was determined through the gravimetric method. Acidity and alkalinity were measured following the titration method. The total hardness was determined using the EDTA complexometric titration method (APHA, 1998). Nitrate and phosphate levels were gauged through alorimetric procedure (APHA,1998). The river discharge was computed following the simple segment method and the average velocity flow through the single float method.

Bacteriological analysis

For bacteriological analysis, another set of water samples was collected using 100 mL sterile sampling bottles. Water samples were brought to the laboratory for heterotrophic plate counts and coliform test.

RESULTS AND DISCUSSION

Results of the analysis of different physical and chemical parameters of water samples collected from the three different sampling areas of Labo and Clarin Rivers are shown in Table 1. Results showed that water temperature varied from 21.0 to 27.0°C with over-all mean of 23.78±1.86°C for

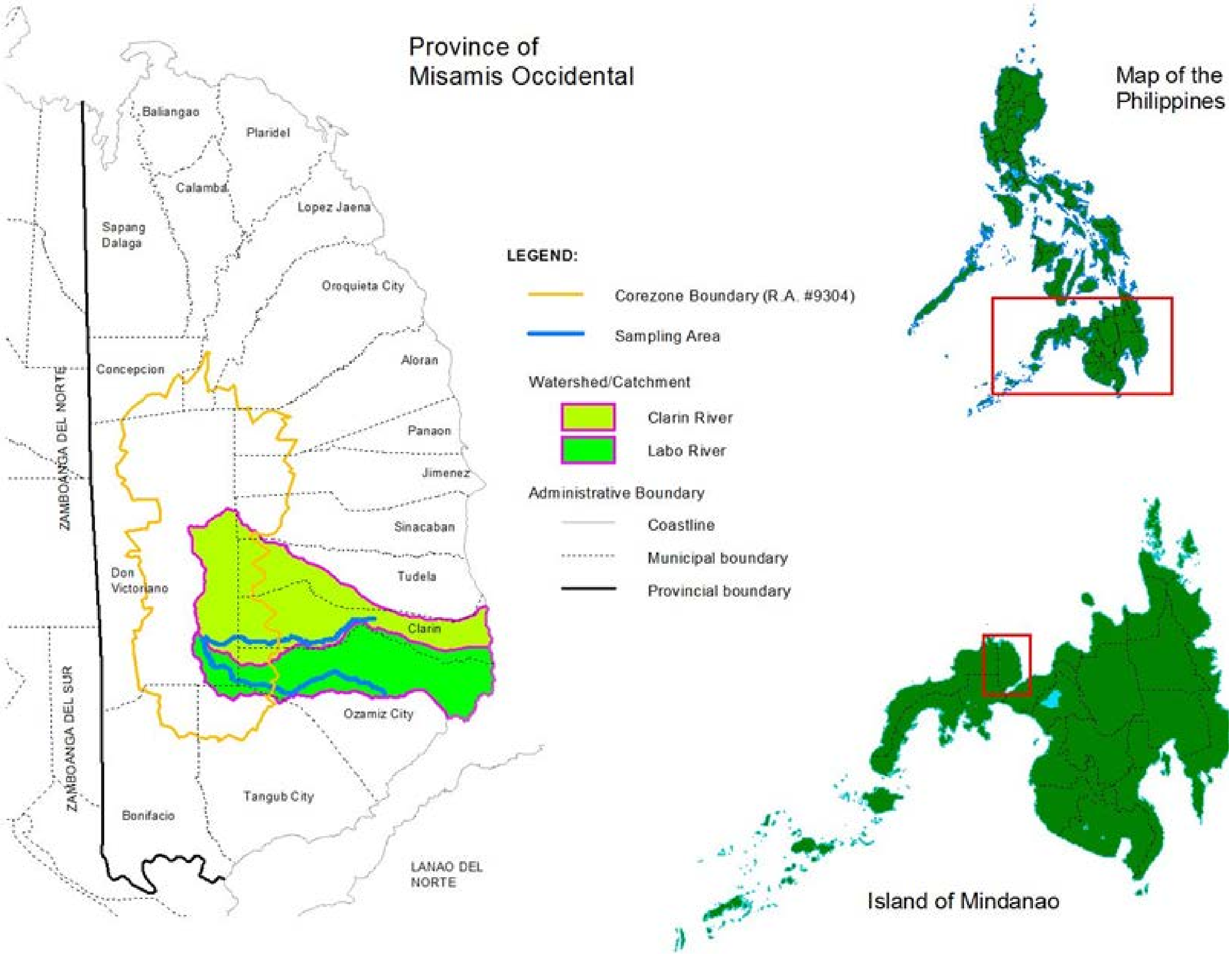

Figure 1. Location map of Labo and Clarin rivers in Misamis Occidental.

Labo River and 18.0 to 24.0°C (22.33±1.80°C) for Clarin River. These are within the normal limits for freshwater standards set by the Department of Environment and Natural Resources (DENR). It means that this temperature will not cause stress to aquatic ecosystems since at this temperature range the water still maintains its ability to hold essential dissolved gases like oxygen (Butcher and Covington, 1995; Lawson, 2011). The water temperature of Labo and Clarin rivers are comparable to the Layawan and Langaran rivers (Roxas et. al., 2005).

The highest average water temperatures were recorded from water samples along the agroforest area of Labo River and in the agricultural area of Clarin River. This is caused by the exposure of water in these areas to direct sunlight because of the lesser number of trees surrounding the water. The shaded water in forested areas of both rivers is much colder than the exposed water in agricultural areas. Touchart et al. (2012) reported that if water is cold, it holds more oxygen which supports more aquatic organisms. On the other hand, as temperature rises, the rate of photosynthesis by algae and larger aquatic plants increases. The faster the plants grow, the faster the plants die and so the decomposition of bacteria that will consume the oxygen. As a result, increasing photosynthesis decreased level of dissolved oxygen in the water (Maxim et al., 2011; Proppe and Harrel, 2007).

Labo River had relatively high turbidity readings (0.18-0.48 NTU) especially from water samples taken along agricultural areas. The severe soil erosion due to quarrying is the major factor that contributes to the high suspended solids in the water. The suspended matter may include the mud, clay and silt (Jayalakshmi et al., 2011). Water samples taken along the forested area were clear with lower turbidity readings of 0.18 to 0.30 NTU (0.25±0.06 NTU). This area has dense vegetation and

Table 1. Physico-chemical analysis of water samples from three sampling stations in Labo and Clarin Rivers.

Parameter	Labo River									Clarin River								Mean±SD
	Forest			Agroforest			Agricultural			Forest			Agroforest			Agricultural		
	N=18			N=18			N=18			N=18			N=18			N=18		
	Min.	Max.	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	
Water temperature (°C)	21.0	22.0	21.67±0.58	24.0	27.0	25±1.73	24.5	26.0	25.17±0.76	18.0	20.0	19.0±1.0	19.0	21.0	20.0±1.0	22.0	24.0	23.0±1.0
Turbidity (NTU)	0.18	0.30	0.25±0.06	0.25	0.31	0.33±0.04	0.39	0.48	0.5±0.02	0.07	0.10	0.14±0.02	0.10	0.12	0.16±0.06	0.10	0.13	0.11±0.04
Total Dissolved Solids (mg/L)	48.0	58.0	52.67±5.03	59.0	67.0	63.33±4.04	65.0	71.0	67.67±3.06	27.0	29	27.83±1.04	40	44	42±2.0	56	63	59±3.61
pH Range	7.98	8.12		7.33	8.27		7.89	8.05		6.92	7.19		6.42	6.97		6.40	6.53	
Acidity (mg/L)	16.05	17.40	16.56±0.73	16.05	17.40	15.63±0.71	17.26	19.20	18.11±0.99	17.90	19.35	18.51±0.75	16.40	17.26	16.92±0.46	15.60	16.24	15.90±0.32
Alkanity (mg/L)	61.10	65.85	63.55±2.38	67.90	72.35	69.62±2.39	75.60	84.55	79.52±4.58	32.60	38.80	36.05±3.16	48.80	53.65	51.30±2.43	55.95	62.30	59.02±3.18
Total Hardness (mg/L as $CaCO_3$)	58.00	68.00	64.00±5.29	69.00	70.00	69.67±0.58	70.00	75.00	72.33±2.52	38.00	41.00	39.67±1.53	49.00	54.00	51.00±2.65	63.00	66.00	64.33±1.53
Calcium (mg/L)	1.62	1.69	1.66±0.04	1.68	1.73	1.70±0.03	1.75	2.02	1.84±0.15	0.68	0.73	0.71±0.03	1.07	1.23	1.14±0.08	1.29	1.45	1.37±0.08
Magnesium (mg/L)	15.08	15.58	15.33±0.25	16.02	16.2	16.10±0.10	16.49	16.78	16.56±0.19	8.90	9.39	9.20±0.27	11.40	12.02	11.65±0.33	14.56	15.75	15.03±0.63
Dissolved oxygen (mg/L)	8.2	10.6	9.3±1.21	5.3	6.4	5.76±0.57	2.4	4.4	3.57±1.04	9.30	11.20	10.40±1.21	6.20	7.80	6.97±0.80	3.90	5.20	4.00±0.32
Biological oxygen demand (mg/L)	0.70	1.10	0.97±0.16	2.00	2.60	2.30±0.30	2.10	3.00	2.50±0.46	0.10	0.40	0.23±0.14	1.50	2.20	1.86±0.30	1.70	2.60	2.03±0.41
Nitrate (mg/L NO_3-N)	0.27	0.50	0.36±0.12	0.40	0.90	0.30±0.17	0.47	0.70	0.56±0.12	0.13	0.47	0.30±0.17	0.37	0.53	0.46±0.08	0.40	0.51	0.45±0.06
Phosphate (mg/L PO_4-P)	0.05	0.09	0.07±0.02	0.06	0.09	0.07±0.01	0.06	0.09	0.08±0.01	0.05	0.08	0.06±0.01	0.04	0.11	0.07±0.04	0.09	0.19	0.137±0.050

Table 1. Contd.

Parameter	LABO RIVER									CLARIN RIVER								Mean±SD
	Forest			Agroforest			Agricultural			Forest			Agroforest			Agricultural		
	N=18			N=18			N=18			N=18			N=18			N=18		
	Min.	Max.	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	Mean±SD	Min	Max	
River discharge (m^3/s)	16.59	21.11	18.31±2.44	8.41	18.07	12.23±5.14	2.25	8.68	5.31±3.22	6.54	9.38	7.76±1.46	2.55	6.96	4.17±2.42	1.33	6.87	3.66±2.87
Average velocity (m/s)	4.00	4.20	4.17±0.15	2.01	3.57	2.77±0.78	2.10	3.50	2.90±0.72	3.27	3.37	3.30±0.06	2.18	3.22	2.71±0.52	1.30	4.74	2.48±1.96

rocky substrate. However, when based on Water Resource Commission (2003), turbidity readings are more than the maximum permissible levels for turbidity that vary from 0-10 NTU.

Clarin River had excellent turbidity readings which ranged from 0.07 to 0.13 NTU due to shallow depth, dense vegetation and rocky substrate causing the water to be clear. The dense vegetation of forest and agroforest beside the Clarin River was observed to have minimized the occurrence of soil erosion.

The total dissolved solid measurements ranged from 27.0 to 71.0 mg/L. Among the sampling areas, the water samples taken along the agricultural area of Labo and Clarin rivers had the highest total dissolved solids with 67.67±3.06 and 59±3.61. mg/L, respectively. Fertilizers from corn-fields and organic matter from untreated sewage contribute higher levels of nitrate and phosphate ions that led to elevated total dissolved solid readings (Dodds and Oakes, 2008). However, these levels of dissolved solids are less than the maximum permissible total dissolved solid concentration (500 mg/L) set by the DENR.

The pH ranged from 6.40 to 8.27. The pH values are within the tolerable range of 6.50-8.50 in most stations except sampling stations 2 and 3 in Clarin River. The slightly acidic water of Clarin river along the agroforest and agricultural areas is attributed to the decaying plants and logs found at the riverbank. As these logs decompose, organic acids are formed resulting in the decrease of water pH. Aquatic organisms are affected by changeable pH. To maintain a reasonably constant pH in the water, it is good to have a higher alkalinity (Addy et al., 2004).

All sampling stations in Labo and Clarin rivers had higher alkalinity ranging from 61.10-84.55 and 32.60-62.30 mg/L, respectively, in concentration of calcium carbonate. These are classified as not sensitive under the US Environmental Protection Agency cateogory. The higher concentration of calcium carbonate implies that the risk of acidification in the water is lower (Craig, 2009).

All sampling stations in Labo river had total hardness of 58.0-75.0 mg/L and is classified by the Water Quality Association (WQA) as moderately hard. In Clarin river, the sampling stations along the forest and agroforest areas had total hardness readings of 38.0-54.0 mg/L and is classified as slightly hard while the stations along the agricultural area were 63.0-66.0 mg/L (64.33±1.53 mg/L) and classified as moderately hard. The moderate degree of water hardness along the agricultural areas of both rivers pointed to the increased amounts of dissolved calcium and magnesium. The relatively high amounts of calcium in the Labo river especially along the agro forest and agricultural areas was observed to be caused by the presence of limestone. As water moves through soils and rocks, calcium and magnesium ions are dissolved and holds them in solution. Hard water is not a health risk (Skipton and Dvorak, 2009). Calcium is essential to aquatic plants as cell wall component and to aquatic organisms as part of the bones and shells.

The dissolved oxygen readings were 2.40-10.60 mg/L in Labor River and 3.90-11.20 mg/L in Clarin River. These are mostly within the DENR standards (≥5 mg/L) except for water along agricultural areas in both rivers. This low level of dissolved oxygen from water along agricultural areas was observed because of the presence of logs and dead plants in the water. Sewage from human settlements nearby and agricultural runoff are additional sources of organic matter (Samantray et al., 2009). Organic materials act as food source for water-borne bacteria. If high levels of organic matter are present in a water, there is an increase in number of bacteria (Ling et al., 2012). The bacteria utilize the oxygen in the water as energy to break down long-chained organic molecules into simpler, more stable end products during the process of decomposition. This results to the depletion of the dissolved oxygen in the water. Moreover, the amount of oxygen that can be held by the water is dependent on the temperature. In agricultural areas, trees that give shade to the water are limited. As a result, water is exposed directly to the sunlight thus increasing the temperature. Warm water holds less oxygen than cold water (Touchart et al., 2012).

The lowest values of biological oxygen demand (BOD) were recorded in forest sampling stations while the highest values were seen in agricultural areas of both rivers. The higher BOD readings in agricultural areas of Labo River (2.10 - 3.0 mg/L) and Clarin River (1.70 - 2.60 mg/L) can be attributed to the increased organic matter from decayed logs and plants and discharges from agricultural runoff and sewage from the nearby human settlements. With the increase quantity of degradable wastes, there will be an increase in abundance of microorganisms (Martinez and Galera, 2011; Jayalakshmi, 2011). However, both rivers have BOD readings below the standard set by DENR-Environmental Management Bureau.

Nitrate levels were found to be 0.13 to 0.90 mg/L NO3-N which are within the DENR standard of 1.0 mg/L NO3-N; however, water samples taken from portions of the two rivers along agricultural areas had relatively high nitrate levels. The use of fertilizers and manures on agricultural lands and domestic sewage increases the amount of nitrates drained into the rivers (Quan and Yan, 2002; Ayebo et al., 2006; Chimwanza et al., 2006). Also, at the time of sampling, domesticated animals such as hogs, cows and horses were found at the vicinity of the river. During rains, water moves as runoff across the surface of the soil and carries the untreated sewage which is a significant source of nitrates (Asriningtyas and Rahayuningsih, 2012). The agricultural area of Clarin River had average phosphate concentration beyond the DENR standard of 0.10 mg/L PO4-P. An increased level of phosphate is due to the presence of people washing clothes and taking a bath during the sampling. Detergent wrappers were found in the vicinity. Detergent contributes to the increase of phosphate in domestic wastes (Cojocariu et al., 2011; Ling et al., 2012). In addition, varying amounts of phosphates are washed from fertilizers used in cornfields and contribute to the high phosphate level (Olajire and Imeokparia, 2001; Quan and Yan, 2002).

The higher river discharges were monitored at the sampling stations along the forest area of both rivers. Labo river had 16.59 - 21.11 m3/s (18.31±2.44 m3/s) while Clarin river had 6.54 - 9.58 m3/s (7.76±1.46 m3/s). Along the forest area is the rolling slope of hillsides that creates waterways allowing rainwater to reach river faster, thus increasing the discharge. On the other hand, the very steep slope along the agricultural area of Labo river especially in station 1 caused the rainwater to run straight over the surface before infiltration.

The average water velocity was also higher in the forest areas of both rivers with an over-all mean of 4.17±0.15 m/s for Labo River and 3.30±0.06 m/s for Clarin River. The forest area is the nearest part where the river starts. On this part, more elevation changes, lesser volume and narrower waterways cause water to move down faster thus higher water velocity. Results of microbial analysis from the water samples collected in three different sampling areas of Labo and Clarin Rivers are shown in Table 2.

Based on the results, water from Clarin River along the forested area is classified as Class A- public water supply with low coliform counts ranging from 2 to 23. This water is not safe for drinking even if the water seems to be very clear unless a complete treatment will be done such as coagulation, sedimentation, filtration and disinfection (DENR-DAO 34, 2005). The water for drinking should be free of coliforms and contain not more than 10 organisms per milliliter of water. The presence of E. coli in water samples is attributed to the direct discharge of faecal wastes of wild pigs, monkeys, birds and humans (Usharani et al., 2010; Kumar and Puri, 2012).

On the other hand, the water from Labo River along the forested area is classified only as Class B-recreational water class 1 which indicates that the water is good only for recreational purposes such as bathing, swimming, skin diving and other activities for tourism purposes. The presence of few households scattered in hilly and mountainous areas contribute to the microbial count in this portion of the river (Dragun et al., 2011; Britz et al., 2013).

There were very high counts (≥1600) of total fecal coliforms that were present (Escherichia coli and Enterobacter aerogenes) in Labo and Clarin rivers along the agroforest and agricultural areas. The water in these areas are classified as Class C/D water which means that the water cannot be used for drinking and is only fit for agriculture, irrigation and industrial purposes. A person swimming in such waters has a greater chance of getting sick from swallowing disease-causing organisms, or from pathogens entering the body through cuts in the skin, the nose, mouth, or the ears. Diseases and illness can be contracted in waters with high fecal coliform counts. There were more households confined near the riverbanks. It was observed during the sampling that lavatories are absent in the households. Aside from corn and other short- term crop farming, many people practice open hog-raising (not contained in a concrete pens) as their common alternative livelihood. During the sampling, cows and carabaos were found along the riverbanks. The fecal contamination is primarily due to eroded wastes from humans, pigs, carabaos and cows (Sh AlOtaibi, 2009; Adetunde et al., 2011).

Conclusion

Most of the physico-chemical properties of Labo and Clarin rivers were within the tolerable range and are not harmful to the aquatic resources. However, water from

Table 2. Average total fecal coliform counts from water samples collected in the sampling areas of Labo and Clarin Rivers.

Sampling sites	Total fecal coliform (MPN/100 mL) Stations 1	2	3	Coliform present	Revised Water Usage and Classification/ Water Quality Criteria (DENR ADMINISTRATIVE ORDER No. 34 Series of 2005)
Labo River					
Forest	17	220	110	*Escherichia coli*	Class B
Agroforest	220	>1600	>1600	*Enterobacter aerogenes and Escherichia coli*	Class C/D
Agricultural	>1600	>1600	>1600	*Enterobacter aerogenes and Escherichia coli*	Class C/D
Clarin River					
Forest	<2	14	23	*Escherichia coli*	Class A
Agroforest	220	900	>1600	*Escherichia coli*	Class C/D
Agricultural	>1600	>1600	>1600	*Enterobacter aerogenes and Escherichia coli*	Class C/D

Classification	Intended Beneficial Use
Class AA	Public Water Supply Class I. This class is intended primarily forwaters having watersheds which are uninhabited and otherwiseprotected and which require only approved disinfection in order tomeet the National Standards for Drinking Water (NSDW) of thePhilippines.
Class A	Public Water Supply Class II. For sources of water supply that willrequire complete treatment (coagulation, sedimentation, filtration and disinfection) in order to meet the NSDW.
Class B	Recreational Water Class I. For primary contact recreation such asbathing, swimming, skin diving, etc. (particularly those designated fortourism purposes).
Class C	1) Fishery Water for the propagation and growth of fish and otheraquatic resources; 2) Recreational Water Class II (Boatings, etc.) 3) Industrial Water Supply Class I (For manufacturing processesafter treatment).
Class D	1) For agriculture, irrigation, livestock watering, etc. 2) Industrial Water Supply Class II (e.g. cooling, etc.) 3) Other inland waters, by their quality, belong to this classification

Based on DENR Revised Water Usage and Quality Criteria.

both rivers are not safe for drinking due to the presence of coliforms.

Conflict of interests

The author(s) have not declared any conflict of interests.

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Research and policy framework for conservation and utilization of edible bamboo in northeast India

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India harbours large bamboo germplasm and most bamboo growth in the country are through human interventions, particularly in the hilly environment. The local communities' associate greater sense of ethics towards this group of plants and are also consumed on a day-to-day basis in different forms. Thus, edible bamboo species gains significance both culturally as well as on economic terms. The strengths and weaknesses of cultivating edible bamboo as a livelihood option in the north-eastern hill (NEH) region has been elucidated through a SWOT analysis in this paper. Over all, a research and policy framework is warranted and integrates the backward and forward linkages of bamboo resource management with the marketing linkages of edible bamboo for sustainable socio-economic development of the hill communities, particularly in the biodiversity rich north-east hill region of India.

Key words: Edible bamboo, conservation, utilization, Northeast India, policy.

INTRODUCTION

India ranks third next to China (300) and Japan (237) in bamboo diversity (Tewari, 1992) and ranks second only to China in bamboo production with 3.23 million tons per year. From a total area of 10.03 million hectares (Sharma, 1980; Biswas, 1988), this constitutes arbout 12.8% of the total area of forest cover in the Country. Out of 125 plant species (represents 23 genera) recorded so far in India, nearly 78 are available in the north-eastern region. Amongst six states of the north-eastern hill (NEH) region, Mizoram occupies largest forest area (30.8%) under different bamboo species (Table 1), followed by Meghalaya with 26.0% (Trivedi and Tripathi, 1984). Environmentally, bamboos have been found to be the best for restoration and short-rotation forestry (Arunachalam and Arunachalam, 2002). On an average, living and litter biomass of bamboo has significantly higher concentration of potassium than dicot trees (Rao and Ramakrishnan, 1989). Owing to their gregariousness and fast growing nature, bamboo form complete colony within 4-5 years of plantation with production of young shoots after 3 year of plantation (Pynskhem et al., 2010). Mature culms are used to make house, flooring, roofing, fencing, for carrying water from long distances and various other day-to-day requirements. Most importantly, the bamboo shoots

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Table 1. Area and distribution of major edible bamboo species in hilly states of the NE region.

State	Geographical area (km^2)	Total forest cover (km^2)	Actual area under bamboo cultivation (km^2)	Potential availability (lakh tons)
Arunachal Pradesh	87,743	51500	7770 (9.50)	2.23
Manipur	22,327	6020	3263 (14.62)	14.48
Meghalaya	22,429	9490	5863 (26.00)	8.25
Mizoram	21,081	13030	6047 (30.81)	6.34
Nagaland	16,579	8620	2405 (22.19)	4.90
Tripura	10,486	6060	2849 (27.13)	5.50

Source: Anonymous, 1999; percentage of area under bamboo species are given in parentheses.

being an intercontinental edible delicacy are typical secondary products exported to Japan, USA, Germany, Saudi Arabia and Denmark by China and Taiwan. In the NEH region, an array of fresh and fragmented bamboo products are prepared for internal consumption. But the biochemistry of edible bamboos has not been given due attention (Bhatt et al., 2001). Nevertheless, the edible species are quite frequently cultivated in home gardens, besides their occurrence in the natural forests. If scientifically explored and validated, the NEH region can share the global export of steamed and canned bamboo shoot to European countries. As this region is the largest reservoir of bamboo resource in India (Table 2), screening is required to find most delicate bamboo species and develop package of practices for their mass multiplication. This paper attempts to evolve a research and policy framework for conservation and utilization of edible bamboo in the country and NEH region in particular.

METHODS

In order to evolve a research and policy framework for edible bamboo utilization and conservation, relevant information from published information with special reference to northeast India were analyzed, based on which, important research and policy issues attributing to management and marketing have been appraised thereof. For holistic analysis of the framework, a SWOT analysis was also exercised, and institutional arrangements were suggested in this paper.

RESULTS AND DISCUSSION

Management of bamboo resources

Being a versatile and renewable resource, bamboo has been over-exploited to the extent that concern is being expressed over erosion of this gene-pool (Renuka, 1996). Over-exploitation affects regeneration of bamboo in their wilderness, apart from mundane flowering. As far as edible species of bamboo are concerned, there are seven genera (Table 2) whose tender shoots are consumed over a prolonged period (Hore, 1998). Such continued extractions could also be limited to the natural regeneration potential, perhaps threatening their survival. This region has witnessed mass flowering of *Melocanna baccifera* during 2005-2007 (Pynskhem et al., 2010). Absence of quality planting material and continued supply of bamboo to paper and pulp industry has significantly affected the livelihood of the humans. Therefore, conservation of this valuable gene pool is warranted for sustainable utilization and profitability. Furthermore, given the climate change scenario, bamboo could contribute tremendously to the carbon sequestration process. Evidently, the recent report on State of Forests in India (FSI, 2011) indicates the role of bamboos and trees outside forest (TOF) in carbon budgeting.

Appreciable research has been carried out on bamboo germplasm collection and resource conservation by various prominent agencies like Forest Departments, Kerala Forest Research Institute (KFRI), State Forest Research Institute (Itanagar), Indian Grassland and Fodder Research Institute (IGFRI), Indian Council of Forestry Research and Education (ICFRE), National Bureau of Plant Genetic Resources (NBPGR), Forest Research Institute (FRI) among several amongst others. Nonetheless, independent research highlighted the importance of bamboo-based agroforestry systems in increasing soil moisture and nutrients, while reducing water run-off and soil erosion (Sharma et al., 1992; Ramakrishnan and Toky, 1981). Due to the shrinking bamboo resources, careful determined and consistently chalked out programme for plantation in farm and forest sector is very much essential.

Being a cross-pollinated species, bamboo exhibits greater variation in wild, which can be utilized in genetic improvement of this species, although bamboo could be successfully grown by sowing of seeds. Nonetheless, most bamboo improvement programmes is based on phenotypic selection, followed by clonal multiplication of superior clumps. Since all the characters of mother clumps are inherited in the progenies, their performance is very much predictable. This is the only method of crop improvement in the case of *Bambusa balcooa*, *Bambusa vulgaris* and *Dendrocalamus strictus* which however do not set seed after flowering. Moreover, the seeds of other bamboo species are short-lived (viability of 1-2 months).

Table 2. Bamboo species in north-eastern states of India.

	Species	Arunachal Pradesh	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Tripura
	Edible Bamboo							
1	*B. balcooa* Roxb.	+	+	-	+	-	+	+
2	*B. bambos* (L.) Voss	+	-	+	-	-	-	-
3	*B. khasiana* Munro	-	-	+	+	-	-	-
4	*B. longispiculata* Gamble ex Brandis	-	-	-	-	+	-	-
5	*B. nutans* Wall. ex Munro	+	+	-	-	-	-	-
6	*B. pallida* Munro	+	+	-	+	+	+	+
7	*B. polymorpha* Munro	+	-	+	+	-	-	+
8	*B. teres Buch*.- Ham. ex Munro	+	+	-	+	-	+	+
9	*B. tulda* Roxb	-	+	-	+	+	+	+
10	*B. vulgaris Schrad*. ex Wendl	-	-	+	-	-	-	-
11	*Chimonobambusa hookeriana* (Munro) Nakai. Synonym *Himalayacalamus hookerianus* (Munro) Stapleton	-	-	-	+	+	-	-
12	*Dendrocalamus brandisii* (Munro) Kurz	-	-	+	-	-	-	-
13	*D. giganteus* Munro	+	+	+	-	-	+	-
14	*D. hamiltonii* Nees et Arn. ex Munro	+	+	+	+	+	+	+
15	*D. hookeri* Munro	+	-	+	+	+	+	-
16	*D. longisphathus* Kurz	-	-	-	-	+	-	+
17	*D. sikkimensis* Gamble	+	-	-	+	-	+	-
18	*D. strictus* (Roxb.) Nees	-	-	-	-	-	-	+
19	*Gigantochloa albociliata* (Munro) Kurz	+	+	-	+	-	-	-
20	*G. apus* (Bl. ex schult. f.) Kurz	-	-	-	+	-	-	-
21	*G. macrostachya* Kurz	-	+	-	+	+	-	-
22	*Himalayacalamus falconeri* (Hook. f. ex. Munro) Keng	+	-	-	-	-	-	-
23	*Melocanna baccifera* (Roxb.) Kurz	-	+	+	+	+	-	+
24	*P. bambusoides* Sieb. and Zucc.	+	-	-	-	-	-	-
	Others							
25	*Arundinaria gracilis* Blanch	+	-	-	-	-	-	-
26	*A. hirsute* munro	+	-	-	-	-	-	-
27	*A. microphylla* Munro	-	-	-	+	-	-	-
28	*A. racemosa* Munro	+	-	-	-	-	-	-
29	*A. rolloana* Gamble	-	-	-	-	-	+	-
30	*Bambusa affinis* Munro	-	-	-	-	-	-	+
31	*B. auriculata* Kurz	-	+	-	-	-	-	-
32	*B. cacharensis* R. Majum	-	+	-	-	-	-	-
33	*B. griffithiana* Munro	-	-	+	-	-	-	-
34	*B. jainthiana* R. Majum	+	+	-	-	-	-	-
35	*B. kingiana* Gamble	-	-	+	-	-	-	-
36	*B. masiersii* Munro	-	+	-	-	-	-	-
37	*B. multiplex* (Lour) Raeusch	+	-	-	-	-	-	-
38	*B. oliveriana* Gamble	-	-	-	-	+	-	-
39	*B. pseudopallida* R. Majum	-	+	-	+	-	-	-
40	*Butania pantlingii* (Gamble) Keng	+	-	-	-	-	-	-
41	*Chimonobambusa callosa* (Munro) Nakai	+	-	+	+	+	+	-
42	*C. griffithiana* (Munro) Nakai	+	-	-	+	+	+	-

Table 2. Contd.

	Species	Arunachal Pradesh	Assam	Manipur	Meghalaya	Mizoram	Nagaland	Tripura
43	*D. catastachyus* (Kurz) Kurz	-	-	-	+	-	+	-
44	*D. patellaris* Gamble	+	+	-	-	-	+	-
45	*D. sachni*i Naithani and Bahadur	+	-	-	-	-	-	-
46	*Dinochloa maclellandii* (Munro) Kurz	-	+	-	-	-	-	-
47	*D. indica* (Majumdar) Bennet	-	+	+	-	-	-	-
48	D. gracilis (Majumdar) Bennet & Jain	-	+	-	-	-	-	-
49	*D. compactiflora* (Kurz) McClure	-	+	-	-	+	-	-
50	*Drepanostachyum hookerearianum* (Munro) Keng	+	-	-	+	+	-	-
51	*D. intermedium* (Munro) Keng	+	-	-	-	-	-	-
52	*D. khasiananum* (Munro) Keng	-	+	+	+	-	-	-
53	*D. kurzii* (Gamble) Pandey	-	-	+	+	-	-	-
54	*D. polystachyum* (King ex Gamble) Pandey	-	-	-	+	-	-	-
55	*D. suberectum* (Munro) Majumdar	+	-	-	+	-	-	-
56	*G. rostrata* Wong	-	+	-	+	-	-	+
57	*Neomicrocalamus clarkei* (Gamble ex Brandis) Pandey	-	-	+	-	-	-	-
58	*N. manii* (Gamble) Pandey	-	-	-	+	-	-	-
59	*N. prainii* (Gmble) Keng	-	-	-	+	-	+	-
60	*Oxytenanthera parvifolia* Brandis ex Gamble	-	+	-	-	+	-	-
61	*Phyllostachys assamica* Gamble ex Brandis	+	+	-	-	-	-	-
62	*P. mannii* Gamble	+	-	-	+	-	-	-
63	*Pleioblastus simonii* (Carr.) Nakai	+	-	-	-	-	-	-
64	*Schizostachyum arunachalensis* Naithani	+	-	-	-	-	-	-
65	*S. capitatum* (Munro) Majumdar	+	-	-	+	+	+	-
66	*S. capitatum* (Munro) Majumdar var. *decompositum* (Gamble) Majumdar	-	-	-	+	-	-	-
67	*S. dullooa* (Gamble) Majumdar	-	+	-	+	+	-	-
68	*S. fuchsianum* (Gamble) Majumdar	+	-	+	-	-	+	-
69	*S. griffithii* (Munro) Majumdar	-	+	-	+	-	-	-
70	*S. helferi* (Munro) Majumdar	-	-	-	+	-	-	-
71	*S. mannii* Majumdar	+	+	+	+	+	+	+
72	*S. pergracile* (Munro) Majumdar	-	+	+	-	-	+	-
73	*S. pallidum* (Munro) Majumdar	+	-	+	+	-	-	-
74	*S. polymorphum* (Munro) Majumdar	+	+	+	+	+	+	-
75	*S. seshagirianum* Majumdar	+	-	-	-	-	-	-
76	*Sinarundinaria longispiculata* Chao and Renvoize	-	-	-	-	+	-	-
77	*Sinobambusa elegans* (Kurz) Nakai	+	-	-	-	-	+	-
78	*Thamnocalamus aristatus* (Gamble) Ca.	+	-	-	-	-	-	-
79	*Yushania maling* (Gamble) R. Majum.	+	-	-	-	-	-	-
	Total	**39**	**29**	**21**	**36**	**20**	**20**	**12**

Nevertheless, no efficient storing techniques have so far been standardized.

For sustainability, harvesting is prescribed every year for culms older than three years under farm sector, and alternate year in the wilderness. Harvesting is not encouraged during active growth period (April-October) and clear felling should be barred in order to prevent degeneration of clumps. Intensive cultural practices to mitigate congestion of clumps in order to facilitate growth of new clumps should be done. Trees providing light sheds should not be removed in the habitat, as the bamboo grow better under shady environment.

In all, bamboo being a multipurpose eco-friendly crop is abundantly available, yet an underutilized natural resource, needs to be managed and exploited for sustainable use. Bamboo is conceived as a thrust area in Industrial Development of NEH Region for the economic and ecological security of the people. This precious resource needs to be fully tapped as an industrial raw material, as substitute for wood in rural/urban housing, engineering works, handicrafts, furniture and value addition through export. Potentially, bamboo can revolutionize the economy of the States ensuring employment opportunities to a large number of people.

Research and policy framework on bamboo

Having the socio-biological principles of the local livelyhoods, the research and development approach should follow the following framework in order to have backward and forward linkages integrated into bamboo resources management and marketing *per se.*

1. Inventory of bamboo and short-listing the edible bamboo through extensive survey.
2. Market survey to understand the bamboo consumption and preparation of detailed inventory of bamboo species.
3. Development of agro-techniques for identified bamboo species for higher yields.
4. Establishment of planting stock for edible bamboos to farmers/growers.
5. Nutritive value analysis of young edible bamboo shoots.
6. Restoration of degraded lands and watershed through potential bamboo germplasm.
7. Evaluation and conservation of economically important bamboo germplasm.

Strategically, the strengths and weaknesses, opportunities and threats of edible bamboo scenario in the NEH region are given in Table 3. Overall, planning and management of bamboo resources could be effective by strengthening inventories, of creation of holistic database on important products and allied information, and economic analysis related to domestic market and export. In NEH region, a critical issue of land/resource tenure has to be resolved by appropriate legislation and policy framework for sustainable management of bamboo resources, as reportedly most land is under private ownership in the region.

Perhaps, we may need to strategically regulate bamboo-exploitation in jhum regrowth and jhum areas by involving Village Councils/Village Forest Development Committees (VFDCs) and eventually facilitating a gradual change to systematic agroforestry management and practices. Sustainable management and use of dedicated bamboo forests and or regrowth areas for providing essential bamboo materials for traditional use and commercial use in bamboo-based industries, enterprises, handicraft sector and also for bamboo trade and commerce (Kharlyngdoh and Barik, 2008) is encounraged. In spite of this fact, shortage of raw material for industry is anticipated in the near future. Therefore, appropriate policy instruments to encourage community and/or private bamboo plantations need to consider subsidy and incentives, apart from the mundane forward and backward linkages.

Simultaneously, expanding market for bamboo in various sector like biochemical, edible shoot, fodder, ornamental, hedge, geotechnical structures for earth reinforcement, low-cost housing and water supply systems for rural masses and handicraft and many other industrial application will be a boost to this sector in the country as a whole, and NEH region in particular. Improving access to appropriate market informations and reducing restriction for domestic market and export as well as reducing fiscal disincentives could help accelerate growth of bamboo sector in India (Nimachow et al., 2010). Capacity building to stakeholders in management of micro-enterprise or a cooperative, availability of mirco-credit for people operating at very subsistence level, value added bamboo processing and design technologies will be beneficial, if adopted under a logical framework in a phased and systematic manner.

Institutional arrangements

Funding support to implement the various policy initiatives enunciated shall be provided from the programme funds of the various development departments (Figure 1). While bamboo resource development within the notified forest area shall be supported by bamboo development projects under centrally sponsored schemes, development of bamboo plantation in agroforestry sector shall be supported from respective programme funds of Agriculture/Horticulture-/Rural Development departments. Special programmes to finance bamboo plantation in farmer sector shall also be supported by Developmental Banks. Establishment of cottage and small and medium sector industries can be supported by government subsidies with due institutional finance from industrial financing agencies and industrial investors/exporters.

Table 3. SWOT analysis of edible bamboo scenario in the NEH region.

Strengths	Weaknesses
- High diversity of edible bamboo in NEH region - Amicable climatic conditions and diverge harvesting seasons - Easy to grow - Low production costs - Processing possibilities: drying, semi fresh packaging - Strong indigenous knowledge systems associated with growing bamboo	- Limited supply - Low productivity due to poor socio-economic condition of the farmers and faulty land tenure system - Non-conventional taste and odour - Lack of storage and processing facilities - Lack of policy frame work for channelization of production, processing and marketing.

Opportunities	Threats
- Diverse range of products and markets - Growing demand of (semi) fresh shoots in the neighboring countries such as Myanmar and Thailand. - High export potential - Development of agro-ecological zone specific farming and production systems using bamboo - Industrial approach to bamboo sector.	- Illegal to trade bamboo shoots - Poor market linkage - Low cost-benefit ratio at times - Loss of traditional knowledge systems - Diversification into high value case crops

States such as Tripura and Mizoram have adopted bamboo policy in the NEH region. In the Valley, the Assam State has bamboo and cane policy, realizing its potential both ecologically and also in economics terms. Nevertheless, a biodiversity rich state like that of Arunachal Pradesh is yet to develop inclusive bamboo policy. Thus, sensitization and thorough awareness of the potential edible bamboo species would only set in remarkable returns that could manifest sustainably in bamboo-based livelihood system in the northeastern hill region in particular.

Conclusion

Despite food self-sufficiency at the national level, the country has not attained food security at a household level particularly in the tribal states of the NEH region. Eventually, a considerable proportion of rural population is still under-nourished and they meet their nutritional requirement through non-conventional means, that is, by consuming various wild plants and animal resources and bamboo shoots. Being at par with various edible fruits leaves, twigs roots and tubers in nutritive value, bamboo resource plays a significant role in the food and nutritional security of the tribal population of the NEH region. Recent break-through in induction of bamboo flowering through appreciation of tissue culture technology (Nadgauda et al., 1990) provides greater opportunities for genetic improvement of bamboo. Further research is needed to study the microelements in various edible species besides studies on homogentisic acid (HGA), which is reported to be responsible for the disagreeable pungent taste of bamboo shoots (Etsuko and Susumu, 1989).

Since there is no systematic documentation on edible bamboo and its utilization pattern tin NEH region, planning priorities should be fixed for exploration, validation, mass multiplication and production of edible bamboo species. Natural death of some of the potential edible bamboo species due to flowering is a serious threat in the region. Hence planning priorities are needed to conserve the germplasm of major edible species of the region. Meanwhile, a few potential species have already been identified along with production potential and cost-benefit analysis (Bhatt and Bujarbaruah, 2003), and hence an inclusive policy framework (Figure 1) shall yield better market prospects that could help improve the quality of bamboo products and also the socio-economic development of indigenous communities that practice bamboo-based livelihoods, considering its potential in the region.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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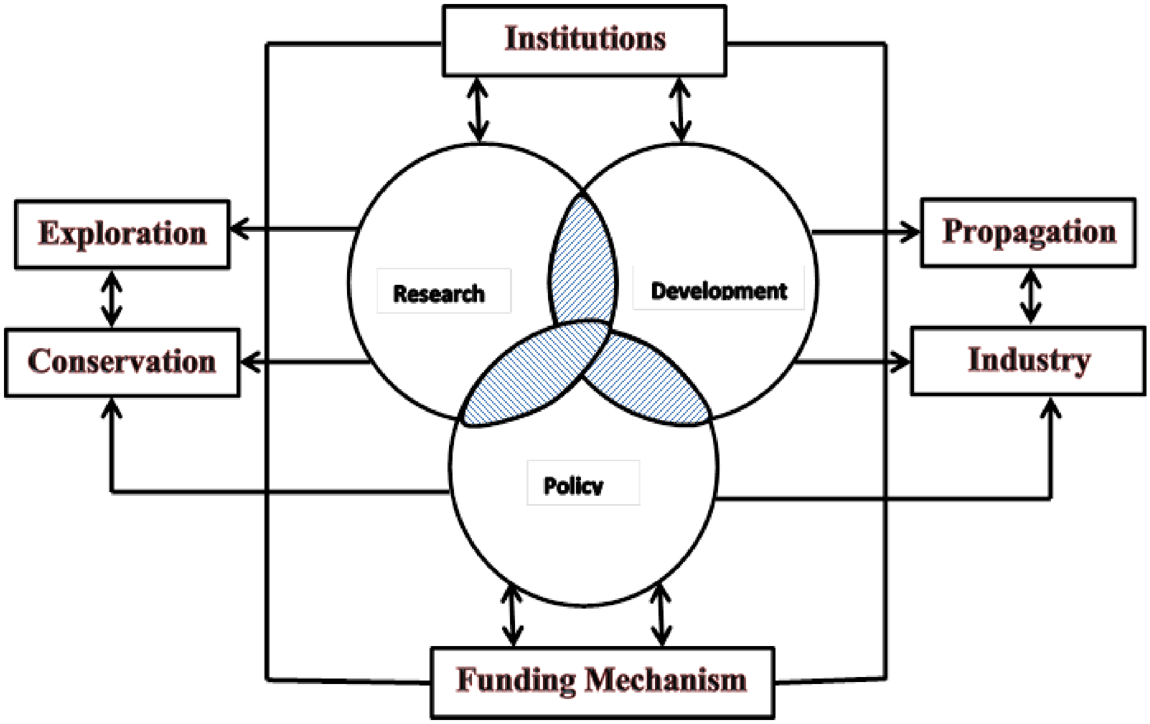

Figure 1. Framework for bamboo utilization and conservation.

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