FLORISTIC COMPOSITION AND VEGETATION STRUCTURE OF THE KNUST BOTANIC GARDEN, KUMASI, GHANA

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ABSTRACT
The diversity, relative importance, canopy height and cover of plant species in the Kwame Nkrumah University of Science and Technology (KNUST) Botanic Garden were evaluated in five 1-ha plots using a stratified random sampling technique in order to build an understanding of its floristic composition and structure in two distinct parts of the garden (cultivated and uncultivated). We recorded 184 species which belonged to 146 genera, 51 families and six growth forms. The most dominant tree species in the garden were Elaeis guineensis Jacq., Hevea brasiliensis (Willd.) Muell.-Arg. and Parkia biglobosa (Jacq.) G. Don. with a combined importance index of 60.09 (20 % relative importance). The differences in importance value indices of species between the cultivated and uncultivated areas of the garden were statistically insignificant (p > 0.05), suggesting the presence of conducive growth environments for plants in both areas. The most dominant families were Fabaceae, Moraceae, Arecaceae and Euphorbiaceae whilst trees were the most predominant growth forms (62.5 %). Average crown height and percentage canopy were 28.8 ± 8.81 m and 66.4 ± 8.26 % respectively. These results show the floristic richness of the KNUST botanic garden and underscore the garden's potential as a centre for ex-situ conservation beside its traditional roles in education, research and recreation.

Keywords: *Floristic composition, structure, botanic garden, KNUST*

INTRODUCTION

Botanic gardens hold documented collections of living plants for the purposes of scientific research, conservation, aesthetic appreciation and education (Willis, 2004). According to the Botanic Garden Conservation International (BGCI, 2005), botanic gardens and arboreta together maintain over four million living plant collections worldwide, most of which are deliberately collected to demonstrate their biological, ecological, taxonomic, evolutionary, conservation, ornamental, historical and cultural values. In Africa, there are only 118 (approximately 5 % of the world's total) of these institutions (Wyse-Jackson and Sutherland, 2000; Willis, 2004). Ghana has five: the Kwame Nkrumah University

of Science and Technology (KNUST) Botanic Garden, University of Ghana Botanic Garden, University of Cape Coast Botanic Garden, Aburi Botanic Garden and the Bunso Arboretum.

The KNUST Botanic Garden is the third largest (12.9 ha) in Ghana and is also listed among the 2000 botanic gardens and arboreta of the world (Willis *et al.*, 2002; BGCI, 2005). The garden has played significant roles in education, research and recreation since its establishment in 1960. This garden, although perceived to be floristically rich (containing tropical palms, timbers and medicinal plants as well as specialised collections of exotic plants), lacks carefully compiled and up-to-date data on the flora. This knowledge gap does not only undermine the effective functioning of the garden, but also fails to depict modern practices and trends in botanic garden management. In most modern botanic gardens, the specialized collections of plants are scientifically arranged, labelled and documented (Willis, 2004).

The rapid disappearance of genetic resources, particularly from the wild, has clearly made botanic gardens important centres for *ex-situ* conservation of the world's biological diversity (Smith *et al.*, 2004). Understanding of the floristic composition and structure of botanic gardens is thus of primary importance in identifying essential elements of plant diversity, protecting threatened and economic species, monitoring the state of the garden and ultimately in the planning and implementation of biological diversity conservation (Tilman, 1988; Ssegawa and Nkuutu, 2006). A systematic floristic inventory is also essential for monitoring the spatial and temporal dynamics that may occur in the garden as a consequence of natural and anthropogenic disturbances (Bhatt *et al.*, 1994).

This study was generally aimed at generating a comprehensive list of plant species in the KNUST Botanic Garden as well as determining the structure of the vegetation. The data gathered is expected to highlight the floristic richness of the garden and serve as baseline information for further research into strategies for the sustainable management of the garden.

MATERIALS AND METHODS

Sampling Sites and Design

The study was conducted in the KNUST Botanic Garden located at the heart of the KNUST campus. Two distinct areas are easily recognizable in the garden: a cultivated area, where most of the plants have been introduced deliberately to enrich the flora; and an uncultivated area which is largely without any introductions of plants and can be described as a secondary forest. Based on this, a stratified random sampling design was employed to locate five 1-ha plots (three in the cultivated and two in the uncultivated) for the study. The plots were demarcated with the help of a field compass and the edges marked with pegs and flags. Each plot was further divided into 16 (25 m x 25 m) subplots. Sampling was done from December, 2005 to April, 2006.

Floristic Composition Determination

The sixteen subplots within each hectare plot were systematically surveyed to identify all trees (diameter at breast height, dbh $\geq$ 10 cm) and their densities determined. The basal areas of the plants were determined from their respective diameters [basal area = π $(dbh/2)^2$]. Densities of shrubs (dbh < 10 cm; height > 1.5 m) were determined in 10 m x 10 m nested plots and 1 m x 1 m nested plots were used to sample herbs and seedlings (< 1.5 m). Epiphytes and climbers were also identified and counted. Identification was done with the help of plant taxonomists. Voucher specimens were collected for plants that could not be identified in the field. These were brought to the Department of Theoretical and Applied Biology, KNUST herbarium for identification. In some cases, standard keys were used to aid in identification (Hutchinson & Dalziel, 1963).

The Cottam and Curtis' Important Value Index (I.V.) which measures the relative importance of species (van Andel, 2003) was computed for all trees as follows:

I. V = Relative density + relative frequency + relative dominance
where,

$$\text{Relative density} = \frac{\text{Number of individuals of a species}}{\text{Total number of individuals}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequencies of all species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of a species}}{\text{Total basal area of all species}} \times 100$$

The Shannon diversity index (H^1) and evenness (E) (Begon *et al*., 1996; Cox, 2002) were also calculated for the trees, shrub and herb layers of the five plots as follows:

$$H^1 = -\sum_{i=1}^{s} pi\ln p_i$$

$$E = \frac{H}{\ln S}$$

where,
p_i = proportion of the ith species
Ln p_i = natural log of pi
E = evenness or equitability
S = species richness

Determination of Canopy Cover and Height
The percentage canopy cover of each hectare plot was determined using a spherical densiometer. Four readings from the four cardinal directions were taken at four different points to obtain an average for each plot. Average canopy height was obtained by measuring the height of ten trees using a clinometer.

Statistical Analysis
Analysis of variance (ANOVA) was performed on the important value indices of species to investigate if any significant difference existed among them. The GenStat Discovery Edition 2 (VSN International Ltd, Hemel Hempstead, UK) software was used, assuming a significance level of 5%.

RESULTS AND DISCUSSION

Floristic Composition of the KNUST Botanic Garden

A total of 184 plant species distributed into 146 genera, 51 families and six growth forms/habits were identified within the five 1-hectare plots sampled in the garden (Table 2), a summary of which is given in Table 1. The list of species obtained is clearly not exhaustive, considering the fact that the data collected could not have been independent of the sample size (Richards, 1996) vis-à-vis the total area of the garden. It however, reflects the diverse composition of the flora in the garden. Apparently, most of the species had become established in the garden as a result of deliberate introductions and successful natural recruitments. The large number of species identified in this study, including 66.3 % natives and 33.7 % exotics (Hutchinson and Dalziel, 1963; Hawthorne, 1990), demonstrates that conditions prevalent in the garden are conducive to plant growth.

In general, tree species diversity was highest at the cultivated portions (H^1 = 3.34 ± 0.45) than the uncultivated portions (H^1 = 2.66 ± 0.85) of the garden (Table 1). This is attributable to the high species richness of the former and the less equitable distribution of individual trees in the latter. For instance, the pararubber plant – *Hevea brasiliensis* (Willd. ex Juss.) Muell.-Arg. – alone accounted for approximately 50 % of all trees in the uncultivated area of the garden. Unlike the cultivated areas, the vegetation in the unculti-

vated areas of the garden appeared to be somewhat loosely protected from anthropogenic disturbances, hence the negative impact on species diversity (Pennisi, 2005). Despite the difference in species diversity, the two areas of the garden surveyed did not differ significantly ($p > 0.05$) with respect to the important value indices of species. This indicates the lack of any strong preference for either part of the garden by the species. It also implies that both sites of the garden offer suitable environments for the growth of all forms of plants.

Table 1: Summary of the floristic composition and vegetation structure of the five one-hectare plots studied in the KNUST botanic garden

Attribute	Cultivated			Uncultivated	
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
Tree Layer ≥ 10cm dbh					
Number of individuals	161	175	163	203	153
Number of species	54[a]	35[a]	63[a]	57[a]	31[a]
Number of families	22[a]	21[a]	32[a]	23[a]	18[a]
Mean diameter of trees (cm)	85.1	90	68	89.5	110
Shannon diversity index (H^1)	3.55	2.83	3.65	3.25	2.07
Shannon evenness (E)	0.88	0.80	0.89	0.79	0.60
Mean canopy height (m)	44 ± 36	23 ± 15	29 ± 22	24 ± 15	24 ± 15
Mean canopy cover (%)	70 ± 9	52 ± 15	68 ± 13	69 ± 9	73 ± 3
Shrub Layer <10cm dbh and height ≥ 1.5m					
Number of individuals	27	0	87	28	84
Number of species	11[a]	0[a]	22[a]	20[a]	24[a]
Number of families	10[a]	0[a]	13[a]	17[a]	15[a]
Shannon diversity index (H^1)	2.03	0	2.64	2.87	2.20
Shannon evenness (E)	0.85	0	0.85	0.96	0.69
Herb Layer < 1.5m					
Number of individuals	183	158	74	74	47
Number of species	21[a]	22[a]	15[a]	17[a]	5[a]
Number of families	19[a]	15[a]	13[a]	13[a]	5[a]
Shannon diversity index (H^1)	2.39	2.66	1.96	0.30	1.41
Shannon evenness (E)	0.79	0.86	0.72	0.11	0.88

[a] *the numbers do not add up to the total number of species and families identified in the study because of overlaps across the two portions of the garden sampled.*

Table 2: List of plant species identified in the KNUST botanic garden with their families, growth habits and important value indices (IVs)

Species	Family	Habit	IV
Acoelorrhape wrightii (Griseb & Wendl.) Britoon[a]	Arecaceae	Tree	0.22
Acridocarpus natalitius A. Juss.	Malpighiaceae	Climber	-
Afzelia africana Sm. ex Pers.	Fabaceae	Tree	1.09
Ageratum conyzoides L.[a]	Asteraceae	Herb	-
Albizia adianthifolia (Schum.) W. F. Wight	Fabaceae	Tree	3.24
Albizia ferrugenia (Guill. & Perr.) Benth.	Fabaceae	Tree	6.10
Albizia zygia (DC.) J. F. Macbr.	Fabaceae	Tree	4.38
Alchornia cordifolia (Schum. & Thonn.) Muel-Arg	Euphorbiaceae	Shrub	-
Allanblackia floribunda A. Chev.	Clusiaceae	Tree	1.32
Aloe macrocarpa Tod.[a]	Aloaceae	Herb	-
Alstonia boonei de Wild	Apocynaceae	Tree	4.02
Amphimas pterocarpoides Harms	Fabaceae	Tree	3.01
Anacardium occidentale L.[a]	Anacardiaceae	Tree	0.32
Anthocleista nobilis G. Don	Loganiaceae	Tree	2.16
Anthocleista vogelii Planch.	Loganiaceae	Tree	0.33
Anthonota macrophylla P. Beauv.	Fabaceae	Tree	2.20
Antiaris toxicaria (Pers.) Lesch.	Moraceae	Tree	9.19
Artocarpus nobilis Thwaites	Moraceae	Tree	1.71
Aspilia africana (Pers.) C. A. Adams	Asteraceae	Herb	-
Aubrevillea kerstingii (Harms) Pellegrin	Fabaceae	Tree	0.97
Axonopus compressus (Sw.) Beauv.	Poaceae	Grass	-
Bambusa vulgaris Schrad. ex Wendl.[a]	Poaceae	Tree-like grass	-
Baphia nitida Lodd	Fabaceae	Shrub	-
Blighia sapida Koenig	Sapindaceae	Tree	1.44
Blighia unijugata Baker	Sapindaceae	Tree	0.86
Bombax buonopozense Beauv.	Bombacaceae	Tree	7.43
Bridelia atroviridis Muell.-Arg.	Euphorbiaceae	Tree	0.91
Bridelia sp.	Euphorbiaceae	Tree	0.37
Calathea cyclophora Baker[a]	Maranthaceae	Herb	-
Canthium hispidum Benth.	Rubiaceae	Climber	-
Carapa procera DC	Meliaceae	Tree	3.46
Caryota mitis Lour.[a]	Arecaceae	Tree	0.25
Cassia nodosa Roxb	Fabaceae	Tree	0.74
Casuarina equisitifolia Forster & Forster.f.[a]	Casuarinaceae	Tree	3.41
Cedrela odorata L.[a]	Meliaceae	Tree	0.37
Ceiba pentandra (L.) Gaertn	Bombacaceae	Tree	6.71

Species	Family	Habit	IV
Centrosema pubescens Benth.[a]	Fabaceae	Herb	-
Chromolaena odorata (L.) King & Robin.[a]	Asteraceae	Shrub	-
Chrysopogon acicularis (Retz.) Trin.[a]	Poaceae	Grass	-
Cinnamomum zeylandicum Breyn.[a]	Lauraceae	Tree	0.42
Citrus aurantifolia (Christm.) Swingle[a]	Rutaceae	Tree	0.48
Citrus nobilis Lour.[a]	Rutaceae	Tree	0.65
Citrus sinensis (L.) Osbeck[a]	Rutaceae	Tree	0.82
Cnestis ferruginea DC.	Connaraceae	Shrub	-
Cola gigantea A. Chev.	Sterculiaceae	Tree	4.97
Cola reticulata A. Chev	Sterculiaceae	Tree	1.83
Cola sp.	Sterculiaceae	Tree	2.63
Colocasia esculenta (L.) Schott.[a]	Araceae	Herb	-
Combretum hispidum C. Lawson[a]	Combretaceae	Climber	-
Combretum sp.	Combretaceae	Tree	1.84
Commelina erecta L.[a]	Commelinaceae	Herb	-
Commelina latifolia C. B. Clarke[a]	Commelinaceae	Herb	-
Culcacia angolensis Welw. ex. Schott.	Araceae	Herb	-
Cyanthillium cinereum (L.) H. E. Robins.[a]	Asteraceae	Herb	-
Cyperus rotundus L.[a]	Cyperaceae	Sedge	-
Dalbergia hostilis Benth.	Fabaceae	Climber	-
Dalbergia sexatilis Hooker f.	Fabaceae	Climber	-
Daniellia ogea (Harms) Rolfe ex Holland	Fabaceae	Tree	0.37
Desmodium adscendens (Sw.) DC.[a]	Fabaceae	Herb	-
Dialum guinense Willd.	Fabaceae	Tree	1.76
Diospyros mespiliformis Hochst. ex A. DC.[a]	Ebenaceae	Tree	1.11
Dioscorea alata L.[a]	Dioscoreaceae	Climber	-
Dioscorea bulbifera Linne	Dioscoreaceae	Climber	-
Dioscorea preusii Pax	Dioscoreaceae	Climber	-
Dioscorea smilacifolia Wildem and Durand.	Dioscoreaceae	Climber	-
Dissotis rotundifolia (Sm.) Triana[a]	Melastomataceae	Herb	-
Distemonanthus benthamianus Baillon	Fabaceae	Tree	1.73
Dracaena arborea (Willd.) Link	Dracaenaceae	Tree	0.32
Dracaena mannii Baker	Dracaenaceae	Tree	0.33
Drypetes sp. Vahl.[a]	Euphorbiaceae	Herb	-
Duranta erecta L.	Verbenaceae	Shrub	-
Echinocereus sp.[a]	Cactaceae	Tree	1.10

Species	Family	Habit	IV
Elaeis guineensis Jacq.	Arecaceae	Tree	34.68
Emilia sanchifolia (L.) DC.	Asteraceae	Herb	-
Entandrophragma angolense (Welw.) D.C	Meliaceae	Tree	0.90
Entandrophragma candollei Harms.	Meliaceae	Tree	1.31
Euadenia trifoliolata (Schum. & Thonn.) Oliv	Capparidaceae	Tree	0.33
Eugenia longiflora (K. Presl.) Fer.- Vill.	Myrtaceae	Tree	0.33
Fadherbia albida (Del.) A. Chev.[a]	Fabaceae	Tree	0.87
Ficus barteri Sprague	Moraceae	Tree	0.51
Ficus exasperata Vahl.	Moraceae	Tree	3.24
Ficus ottoniifolia (Miq.) Miq.	Moraceae	Epiphyte	-
Ficus ovata Vahl.	Moraceae	Epiphyte	-
Ficus polita Vahl.	Moraceae	Epiphyte	-
Ficus saussureana DC	Moraceae	Tree	0.26
Ficus tessellata Warb.	Moraceae	Epiphyte	-
Ficus thonningii Blume	Moraceae	Epiphyte	-
Ficus trichopoda Baker	Moraceae	Epiphyte	-
Ficus umbellata Vahl	Moraceae	Epiphyte	-
Ficus vogelii (Miq.) Miq	Moraceae	Epiphyte	-
Ficus vogelii var. pubicarpa	Moraceae	Epiphyte	-
Funtumia elastica (Preuss) Stapf.	Apocynaceae	Tree	1.06
Garcinia gnetoides Hutch. & Dalz.[a]	Myrtaceae	Tree	3.28
Griffonia simplicifolia (Vahl ex DC) Baillon	Fabaceae	Shrub	-
Hevea brasiliensis (Willd. ex Juss.) Muell.-Arg[a]	Euphorbiaceae	Tree	14.52
Hippocratea africana (Wild.) Loesener ex Engler	Celastraceae	Climber	-
Hippocratea macrophylla Vahl.	Celastraceae	Climber	-
Holarrhena floribunda (G. Don) Durand & Schinz.	Apocynaceae	Tree	2.43
Howea forsteriana Becc.[a]	Arecaceae	Tree	1.50
Ipomoea involucrata P. Beauv[a]	Convolvulaceae	Climber	-
Justicia flava Vahl.[a]	Acanthaceae	Herb	-
Lannea welwitschii (Hiern) Engl.	Anacardiaceae	Tree	1.62
Leucaena leucocephala (Lam.) de Wit.[a]	Fabaceae	Tree	3.22
Licuala peltata.(Roxb. ex Buch) Ham[a]	Arecaceae	Tree	1.18
Livistonia sp.[a]	Arecaceae	Tree	0.72
Lophira alata Banks ex Gaertn.f.	Ochnaceae	Tree	1.00

Species	Family	Habit	IV
Macaranga hurifolia Beille.	Euphorbiaceae	Tree	0.42
Mallotus oppositifolius (Geiseler) Muell-Arg[a]	Euphorbiaceae	Shrub	-
Mangifera indica L.[a]	Anacardiaceae	Tree	5.54
Mansonia altissima A. Chev.	Sterculiaceae	Tree	0.42
Mareya micrantha (Benth.) Muell-Arg.	Euphorbiaceae	Tree	1.55
Milicia excels (Welw.) C. C. Berg.	Moraceae	Tree	1.10
Millittia rhodantha Baillon	Fabaceae	Tree	0.31
Mitragyna stipulosa (DC) O. Kuntze[a]	Rubiaceae	Tree	0.40
Momordica angustisepala Harms.	Cucurbitaceae	Climber	-
Morinda lucida Benth.	Rubiaceae	Tree	7.59
Morus mesozygia Stapf.	Moraceae	Tree	2.32
Motandra guinensis (Thonn.) DC	Apocynaceae	Climber	-
Myrianthus arboreus P. Beauv.	Moraceae	Tree	1.97
Myrianthus libericus Rendle	Moraceae	Tree	0.28
Nephrolepis biserrata (Sw.) Schott[a]	Nephrolepidaceae	Herb (fern)	-
Nesogordonia papaverifera (A. Chev.) R Capuron	Sterculiaceae	Tree	0.43
Oplismenus burmanii (Retz.) Beauv.	Poaceae	Grass	-
Oxalis corniculata L.	Oxalidaceae	Herb	-
Parkia biglobosa (Jacq.) R. Br. ex G. Don.	Fabaceae	Tree	10.89
Parkia filicoidea Welw. ex Oliver	Fabaceae	Tree	1.49
Parquetina nigrescens (Afzel.) Bullock.	Periplocaceae	Climber	-
Paspalum notatum Flugge[a]	Poaceae	Grass	-
Peltophoreum pterocarpum (DC.) Backer ex Heyne[a]	Fabaceae	Tree	5.63
Pereskia bleo (Kunth) DC[a]	Cactaceae	Tree	0.47
Phoenix dactylifera L.[a]	Arecaceae	Tree	1.55
Phoenix reclinata Jacq.[a]	Arecaceae	Tree	2.30
Phyllanthus amarus Schum. & Thonn.	Euphorbiaceae	Herb	-
Phyllanthus discoideus (Baill.) Muell.-Arg.	Euphorbiaceae	Herb	-
Pinus caribaea Morelet.[a]	Pinaceae	Tree	1.17
Piper guineense Schum. and Thonn.	Piperaceae	Climber	-
Piptadeniastrum africanum (Hook. f.) Brenan	Fabaceae	Tree	3.36
Pritchardia affinis Becc.[a]	Arecaceae	Tree	1.00
Pseudospondias microcarpa (A. Rich) Engl.	Anacardiaceae	Tree	8.75
Psidium guajava L.[a]	Myrtaceae	Tree	0.37

Species	Family	Habit	IV
Psidium littorale Raddi[a]	Myrtaceae	Tree	1.22
Psydrax subcordata (DC) Bridson	Rubiaceae	Tree	3.51
Ptychosperma macarthirii (H. Wedl. ex Veitch) H. Wedl. ex Hook. f.[a]	Arecaceae	Tree	0.10
Pycnanthus angolensis (Welw.) Warb.	Myristicaceae	Tree	0.88
Raphia hookeri L.	Arecaceae	Tree	6.06
Raphidosphora africana N. E. Br.	Araceae	Climber	-
Rauvolfia vomitoria Afzelius	Apocynaceae	Tree	2.09
Reissantis indica (Willd.) Halle	Celastraceae	Climber	-
Ricinodendron heudelotii (Baill.) Heckel	Euphorbiaceae	Tree	2.35
Rothmannia longiflora Salisb.	Rubiaceae	Tree	2.07
Roystonea regia (Kunth.) Cook[a]	Arecaceae	Tree	1.40
Sabal palmetto (Walt.) Lodd.[a]	Arecaceae	Tree	2.02
Salacia alata De. Wild.	Celastraceae	Climber	-
Salacia reticulata Wight[a]	Celastraceae	Shrub	-
Salix babylonica L.	Saliaceae	Shrub	-
Scleria naumaniana Boeck.	Cyperaceae	Sedge	-
Solanum erianthum D. Don	Solanaceae	Shrub	-
Spathodea campanulata Beauv.	Bignoniaceae	Tree	1.46
Spondias mombin L.	Anacardiaceae	Tree	0.72
Sporobollus pyramidalis Beauv.[a]	Poaceae	Grass	-
Sterculia rhinopetala K. Schum	Sterculiaceae	Tree	0.57
Sterculia tragacantha Lindley	Sterculiaceae	Tree	3.37
Strophanthus barteri Franch.	Apocynaceae	Climber	-
Strychnos nux-vomica L.[a]	Loganiaceae	Tree	1.32
Synedrella nodiflora (L.) Gaertn.	Asteraceae	Herb	-
Tabebuia chrysantha G. Nicholson[a]	Bignoniaceae	Tree	6.76
Tacca sp.[a]	Taccaceae	Herb	-
Tamarindus indica L.[a]	Fabaceae	Tree	0.82
Terminalia ivorensis A. Chev.	Combretaceae	Tree	4.10
Terminalia superba Engl. & Diels.	Combretaceae	Tree	1.14
Tetrapleura tetraptera (Schum. & Thonn.) Taubert	Fabaceae	Tree	0.53
Tetrorchidium didymostemon (Baill.) Pax & K. Hoffm	Euphorbiaceae	Tree	0.69
Theobroma cacao L[a]	Sterculiaceae	Tree	1.14
Trema orientalis (L.) Blume	Ulmaceae	Tree	0.71
Trichilia prieuriana A. Juss.	Meliaceae	Tree	2.47
Trichilia monadelpha (Thonn.) de Wild.	Meliaceae	Tree	0.49

Species	Family	Habit	IV
Triplochiton scleroxylon Schum.	Sterculiaceae	Tree	0.98
Urochloa maxima (Jacq.) R. Webster	Poaceae	Grass	-
Veitchia arecina Becc.[a]	Arecaceae	Tree	0.50
Vitex trifolia L.	Verbenaceae	Tree	0.39
Voacanga africana Stapf.	Apocynaceae	Tree	0.97
Wallichia densiflora Mart.[a]	Arecaceae	Tree	1.06
Xylopia aethiopica (Dunal.) A Rich.	Annonaceae	Tree	4.29
Zanthoxylum xantholoides Waterm	Rutaceae	Tree	3.00

[a]*Exotic species*

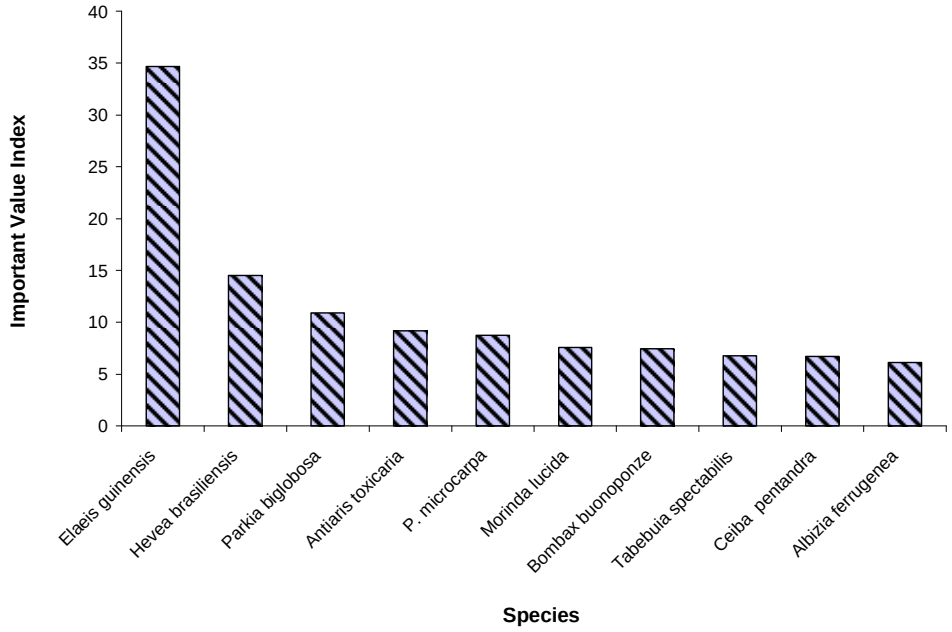

Fig. 1: Relative importance of the most dominant trees identified in the KNUST botanic garden

The important value index (IV) is a measure of the relative importance of a species in an area and combines such attributes as relative density, relative frequency and relative dominance (van Andel, 2003). Based on this, *Elaeis guineensis* Jacq. emerged as the most important species, recording an index value of 34.68. This was followed by *H. brasiliensis* and *Parkia biglobosa* (Jacq.) R. Br. Ex G. Don with IVs of 14.52 and 10.89 respectively (Fig. 1). The remaining species had IVs below 10. The important value indices of the species differed significantly ($df = 117$, $p < 0.001$). This supports the observation that some species were more dominant in the

garden than others. The three most important species, which together had approximately 20 % dominance, are all economically important species and might have been intentionally introduced into the garden or received a little more attention than other species. Besides, *E. guineensis* and *P. biglobosa* are native plants, implying that they can thrive in most environments in the tropics. *H. brasiliensis* formed a monoculture of about 50 m^2 area in the garden.

Fabaceae was the most species-rich family (24 species), followed by Moraceae, Arecaceae (Palmae) and Euphorbiaceae with 18, 15 and 12 species respectively. The 47 remaining families together had a total of 115 species (62.5 % of species identified in the garden), with as many as 25 families recording single species each (Table 2, Fig. 2). With respect to the number of individuals, however, the importance or dominance was highest in the Arecaceae, followed by Euphorbiaceae, Fabaceae and Moraceae, in decreasing order (Fig. 2). The dominance of Arecaceae (Palmae) is largely attributable to the wide distribution of *E. guineensis* in the garden. On the other hand, the epiphytic habit of most of the species of Moraceae, and their preference for specific host trees (Munoz *et al*., 2003), may explain the fewer number of individuals recorded for this family. It is noteworthy that, apart from being naturally large (Langenheim and Thimann, 1982; Watson and Dallwitz, 2002), most of the species in these families (except those of Arecaceae) are native tropical plants which can thrive under tropical conditions.

The species identified in the botanic garden naturally fell into six growth forms or habits namely trees, broadleaf herbaceous plants, shrubs, epiphytes, grasses/sedges and climbers/ lianas. The trees were the most diverse growth

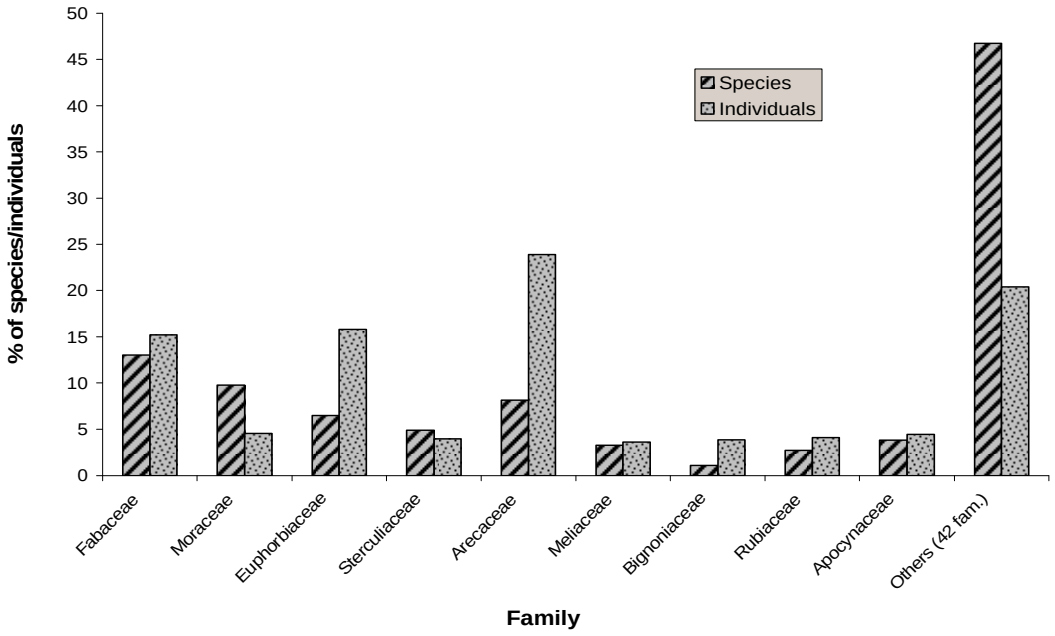

Fig. 2: Family dominance of flora in the KNUST botanic garden based on percentages of individuals and species of trees

form, accounting for 62.5 % of all species encountered in the garden, whilst epiphytes and grasses/sedges were the least common (Fig. 3). The ground layer of the cultivated part of the garden is regularly mowed to create opportunities for recreation, retreats and other end-uses. This practice appeared to have had a negative impact on the shrub composition of the garden as observed in portions of the cultivated area where no shrub was recorded (Table 1). On the contrary, availability of light, resulting mainly from the sparse spatial distribution of trees (Riffell and Gutzwiller, 1996; Pabst and Spies, 1998) coupled with the increasing accessibility to humans, appeared to have impacted positively on the herb diversity in the cultivated areas.

Vegetation Structure of the Garden

The diameter (basal area), height and percentage cover of trees in the KNUST Botanic Garden were measured to emphasize their importance in determining the garden's vegetation structure. The mean values of all three attributes were high (Table 1), suggesting the predominance of mature closed forest vegetation in the garden. Mean canopy cover and diameter of trees in the uncultivated part of the garden (71 % and 99.75 cm respectively) were higher compared to the cultivated, again indicating the relatively less anthropogenic interventions in the former part of the garden (Table 1). Canopy height was however higher in most parts of the cultivated area (23 – 44 m) than the uncultivated area (24 m). Some emergents, including *Ricinodendron heudelotti (*Baill.) Pierre *ex* Pax. and *Entandrophragma candollei* Kosipo, were common, again indicating the mature nature of the vegetation.

CONCLUSION

The study produced a comprehensive but incomplete list of plant species including medicinal plants, timbers, edibles/spices and other com-

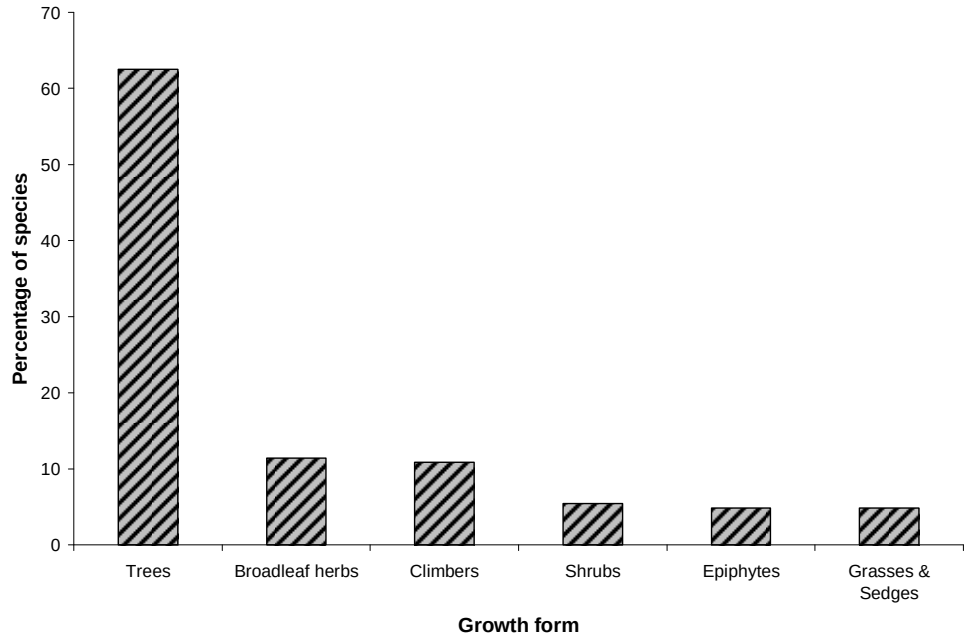

Fig. 3: Growth forms of plant species encountered in the study area

mercial plants. This will serve as a good reference list for future studies aimed at understanding or monitoring the spatio-temporal dynamics of vegetation in the KNUST botanic garden. It will also be a good baseline data for the development of a plant resource database for the garden. Further, with their important value indices determined, it will be easier to prioritize the species for conservation or management. The high numbers of both native and exotic plant species recorded in this study sufficiently demonstrates the garden's potential as an *ex-situ* conservation centre besides its traditional roles. In this regard, propagules of species locally extinct or threatened from some habitats could be obtained from the garden for reintroduction into the wild and vice versa due to the prevailing equable growth conditions.

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Appendix A

Distribution of Incomes of Households in Nkoranza District for 2000 and 2004 (in Ghana Cedis)

Households A (HA)			Households B (HB)			HA	HB
Individual	Income (2000)	Income (2004)	Individual	Income (2000)	Income (2004)	%ΔHA	%ΔHB
HA 80	0.19	0.23	HB50	0.20	0.25	21.05	25.00
HA 76	0.20	0.25	HB75	0.21	0.30	25.00	42.86
HA64	0.20	0.30	HB1	0.22	0.39	50.00	77.27
HA1	0.25	0.33	HB55	0.27	0.39	32.00	44.44
HA10	0.28	0.40	HB5	0.30	0.39	42.86	30.00
HA33	0.28	0.40	HB11	0.30	0.40	42.86	33.33
HA53	0.30	0.40	HB28	0.35	0.43	33.33	22.86
HA55	0.30	0.40	HB94	0.36	0.45	33.33	25.00
HA45	0.30	0.42	HB17	0.38	0.45	40.00	18.42
HA57	0.32	0.45	HB24	0.39	0.48	40.63	23.08
HA2	0.32	0.47	HB81	0.39	0.50	46.88	28.21
HA30	0.34	0.48	HB20	0.40	0.50	41.18	25.00
HA43	0.35	0.48	HB9	0.42	0.50	37.14	19.05
HA34	0.35	0.50	HB13	0.45	0.55	42.86	22.22
HA36	0.37	0.50	HB23	0.45	0.55	35.14	22.78
HA63	0.38	0.50	HB63	0.47	0.56	31.58	19.15
HA44	0.38	0.51	HB59	0.49	0.56	34.21	14.29
HA70	0.40	0.53	HB10	0.50	0.58	32.50	16.00
HA37	0.40	0.55	HB68	0.53	0.58	37.50	9.43
HA72	0.40	0.55	HB37	0.58	0.60	37.50	3.45
HA9	0.42	0.60	HB37	0.58	0.60	42.86	3.45
HA52	0.45	0.60	HB12	0.59	0.60	33.33	1.69
HA58	0.45	0.60	HB72	0.59	0.60	33.33	1.69
HA21	0.45	0.63	HB52	0.60	0.60	40.00	0.00
HA68	0.45	0.64	HB79	0.60	0.64	42.22	6.67
HA74	0.48	0.64	HB88	0.60	0.65	33.33	8.33
HA8	0.50	0.65	HB100	0.61	0.65	30.00	6.56
HA29	0.50	0.69	HB53	0.62	0.65	38.00	4.84
HA46	0.50	0.69	HB74	0.63	0.68	38.00	7.94
HA97	0.52	0.69	HB84	0.63	0.68	32.69	7.94
HA82	0.52	0.70	HB92	0.63	0.68	34.62	7.94
HA27	0.54	0.71	HB32	0.65	0.68	31.48	4.62
HA40	0.54	0.71	HB33	0.65	0.69	31.48	6.15
HA12	0.54	0.75	HB56	0.68	0.69	38.89	1.47
HA86	0.54	0.75	HB80	0.68	0.69	38.89	1.47
HA15	0.60	0.78	HB18	0.69	0.70	30.00	1.45

Households A (HA)			Households B (HB)			HA	HB
Individual	**Income (2000)**	**Income (2004)**	**Individual**	**Income (2000)**	**Income (2004)**	**%ΔHA**	**%ΔHB**
HA28	0.60	0.78	HB38	0.69	0.70	30.00	1.45
HA60	0.62	0.79	HB60	0.69	0.70	27.42	1.45
HA5	0.64	0.80	HB19	0.70	0.70	25.00	0.00
HA24	0.65	0.80	HB43	0.70	0.70	23.08	0.00
HA83	0.65	0.80	HB76	0.70	0.70	23.08	0.00
HA100	0.68	0.80	HB78	0.70	0.70	17.65	0.00
HA13	0.70	0.83	HB45	0.71	0.70	18.57	-1.41
HA26	0.70	0.83	HB26	0.73	0.71	18.57	-2.74
HA48	0.70	0.83	HB29	0.73	0.72	18.57	-1.37
HA50	0.70	0.83	HB71	0.74	0.73	18.57	-1.35
HA41	0.72	0.85	HB96	0.74	0.74	18.06	0.00
HA51	0.74	0.85	HB22	0.75	0.75	14.86	0.00
HA85	0.74	0.85	HB34	0.75	0.79	14.86	5.33
HA4	0.74	0.86	HB47	0.75	0.79	16.22	5.33
HA54	0.75	0.86	HB64	0.75	0.80	14.67	6.67
HA67	0.78	0.90	HB82	0.75	0.80	15.38	6.67
HA79	0.78	0.90	HB40	0.76	0.80	15.38	5.26
HA14	0.80	0.91	HB41	0.78	0.80	13.75	2.56
HA49	0.80	0.91	HB48	0.78	0.80	13.75	2.56
HA84	0.80	0.91	HB62	0.78	0.82	13.75	5.13
HA3	0.84	0.92	HB14	0.80	0.83	9.52	3.75
HA22	0.85	0.92	HB30	0.80	0.83	8.24	3.75
HA32	0.85	0.92	HB73	0.80	0.89	8.24	11.25
HA7	0.86	0.93	HB97	0.80	0.90	8.14	12.50
HA31	0.88	0.93	HB16	0.85	0.90	5.68	5.88
HA78	0.88	0.93	HB27	0.89	0.90	5.68	1.12
HA99	0.90	0.94	HB2	0.90	0.90	4.44	0.00
HA81	0.90	0.94	HB4	0.90	0.90	4.44	0.00
HA11	0.90	0.94	HB35	0.90	0.90	4.44	0.00
HA25	0.90	0.95	HB51	0.90	0.90	5.56	0.00
HA18	0.90	0.95	HB67	0.90	0.90	5.56	0.00
HA39	0.90	0.95	HB86	0.90	0.90	5.56	0.00
HA47	0.90	0.95	HB7	0.91	0.90	5.56	-1.10
HA66	0.90	0.95	HB57	0.91	0.91	5.56	-0.55
HA95	0.90	0.96	HB65	0.91	0.91	6.67	-0.55
HA90	0.90	0.96	HB42	0.92	0.91	6.67	-1.09
HA20	0.90	0.98	HB49	0.92	0.92	8.89	0.00
HA16	0.90	1.00	HB66	0.92	0.93	11.11	0.54
HA73	0.91	1.00	HB85	0.92	0.93	9.89	1.09

Households A (HA)			Households B (HB)			HA	HB
Individual	**Income (2000)**	**Income (2004)**	**Individual**	**Income (2000)**	**Income (2004)**	**%ΔHA**	**%ΔHB**
HA96	0.92	1.00	HB95	0.92	0.93	8.70	1.09
HA93	0.92	1.20	HB98	0.92	0.94	30.43	2.17
HA38	0.92	1.20	HB36	0.93	0.94	30.43	1.08
HA6	0.94	1.20	HB77	0.94	0.95	27.66	0.53
HA56	0.95	1.20	HB93	0.95	0.95	26.32	0.53
HA98	0.95	1.35	HB70	0.95	0.95	42.11	0.00
HA91	0.95	1.35	HB6	0.95	0.96	42.11	1.05
HA35	0.95	1.40	HB25	0.96	0.96	47.37	0.00
HA17	0.98	1.40	HB44	0.96	0.96	42.86	0.00
HA71	1.00	1.40	HB99	0.97	0.97	40.00	0.52
HA87	1.00	1.40	HB69	0.97	0.97	40.00	0.00
HA59	1.00	1.40	HB83	0.99	0.98	40.00	-0.51
HA19	1.10	1.50	HB39	1.00	1.00	36.36	0.00
HA23	1.20	1.50	HB90	1.00	1.10	25.00	10.00
HA42	1.20	1.50	HB87	1.20	1.15	25.00	-4.17
HA75	1.20	1.50	HB15	1.20	1.20	25.00	0.00
HA69	1.20	1.80	HB90	1.30	1.25	50.00	-3.85
HA65	1.30	1.80	HB31	1.30	1.25	38.46	-3.85
HA94	1.50	1.80	HB58	1.30	1.30	20.00	0.00
HA61	1.50	2.00	HB91	1.30	1.30	33.33	0.00
HA88	1.50	2.00	HB61	1.30	1.35	33.33	3.85
HA62	1.50	2.20	HB46	1.40	1.41	46.67	0.71
HA89	1.80	2.50	HB21	1.42	1.55	38.89	9.15
HA92	1.80	2.60	HB54	1.50	1.70	44.44	13.33
HA77	2.00	2.60	HB8	1.65	1.80	30.00	9.09

Source: *Field Survey, 2004*

Appendix B
Distribution of Incomes of Households in Wenchi District for 2000 and 2004 (in Ghana Cedis)

Households A (HA)			Households B (HB)			HA	HB
Individual	Income (2000)	Income (2004)	Individual	Income (2000)	Income (2004)	%ΔHA	%ΔHA
HA56	0.19	0.20	HB84	0.19	0.20	5.26	5.26
HA79	0.20	0.20	HB12	0.21	0.20	2.56	-4.76
HA74	0.20	0.33	HB24	0.30	0.30	65.00	0.00
HA81	0.22	0.33	HB43	0.35	0.32	50.00	-8.57
HA92	0.23	0.34	HB82	0.36	0.36	47.83	0.00
HA71	0.25	0.40	HB81	0.37	0.38	60.00	2.70
HA72	0.26	0.41	HB22	0.40	0.41	57.69	2.50
HA95	0.30	0.41	HB2	0.43	0.42	36.67	-2.33
HA91	0.32	0.41	HB31	0.45	0.45	28.75	0.00
HA99	0.32	0.43	HB66	0.48	0.49	34.38	2.08
HA83	0.33	0.48	HB68	0.49	0.50	45.45	2.04
HA76	0.34	0.50	HB80	0.50	0.50	47.06	0.00
HA97	0.35	0.52	HB88	0.50	0.52	48.57	4.00
HA23	0.36	0.53	HB79	0.55	0.55	47.22	0.00
HA69	0.37	0.53	HB1	0.55	0.55	43.24	-0.45
HA49	0.38	0.56	HB30	0.56	0.57	47.37	1.79
HA51	0.39	0.58	HB87	0.56	0.57	48.72	1.79
HA50	0.40	0.59	HB18	0.58	0.58	47.50	0.00
HA13	0.41	0.60	HB42	0.58	0.59	46.34	1.72
HA31	0.42	0.60	HB35	0.60	0.61	42.86	1.67
HA60	0.42	0.60	HB41	0.60	0.62	42.86	3.33
HA78	0.43	0.60	HB50	0.60	0.62	39.53	3.33
HA93	0.44	0.64	HB58	0.60	0.63	45.45	5.00
HA34	0.45	0.65	HB99	0.60	0.63	44.44	5.00
HA66	0.47	0.65	HB65	0.64	0.65	38.30	1.56
HA82	0.48	0.65	HB75	0.65	0.65	35.42	0.00
HA94	0.50	0.65	HB77	0.65	0.66	30.00	1.54
HA19	0.51	0.67	HB90	0.65	0.67	31.37	3.08
HA20	0.51	0.68	HB20	0.68	0.69	33.33	1.47
HA10	0.52	0.69	HB23	0.68	0.68	32.69	0.00
HA45	0.52	0.69	HB64	0.68	0.69	32.69	1.47
HA90	0.53	0.69	HB71	0.68	0.69	30.19	1.47
HA22	0.54	0.70	HB47	0.69	0.69	29.63	0.00
HA35	0.55	0.70	HB89	0.69	0.70	27.27	1.45
HA36	0.56	0.70	HB93	0.68	0.71	25.00	4.41

Households A (HA)			Households B (HB)			HA	HB
Individual	**Income (2000)**	**Income (2004)**	**Individual**	**Income (2000)**	**Income (2004)**	**%ΔHA**	**%ΔHA**
HA55	0.58	0.70	HB19	0.70	0.72	20.69	2.14
HA42	0.59	0.71	HB34	0.70	0.72	20.34	2.14
HA43	0.60	0.74	HB39	0.70	0.72	23.33	2.86
HA6	0.61	0.75	HB48	0.70	0.72	22.95	2.86
HA25	0.63	0.75	HB52	0.70	0.72	19.05	2.86
HA84	0.65	0.78	HB53	0.70	0.73	20.00	4.29
HA30	0.67	0.80	HB85	0.70	0.73	19.40	4.29
HA61	0.69	0.80	HB91	0.70	0.73	15.94	4.29
HA86	0.70	0.81	HB70	0.71	0.73	15.71	2.82
HA48	0.71	0.82	HB6	0.72	0.74	15.49	2.78
HA67	0.71	0.83	HB73	0.73	0.74	16.90	1.37
HA17	0.72	0.85	HB10	0.74	0.75	18.06	1.35
HA8	0.73	0.90	HB29	0.75	0.75	23.29	0.00
HA18	0.74	0.90	HB78	0.79	0.76	21.62	-3.80
HA21	0.75	0.90	HB97	0.79	0.77	20.00	-2.53
HA37	0.75	0.90	HB7	0.80	0.78	20.00	-2.50
HA46	0.76	0.90	HB8	0.80	0.79	18.42	-1.25
HA53	0.77	0.90	HB14	0.80	0.81	16.88	1.25
HA68	0.79	0.90	HB27	0.80	0.82	13.92	2.50
HA98	0.80	0.90	HB96	0.80	0.83	12.50	3.75
HA2	0.82	0.91	HB32	0.82	0.83	10.98	1.22
HA85	0.83	0.91	HB26	0.83	0.84	9.64	1.20
HA89	0.84	0.91	HB67	0.83	0.85	8.33	2.41
HA14	0.85	0.92	HB83	0.89	0.88	8.24	-1.12
HA73	0.86	0.92	HB21	0.90	0.91	6.98	1.11
HA4	0.87	0.93	HB25	0.90	0.91	6.90	1.11
HA9	0.88	0.93	HB40	0.90	0.92	5.68	2.22
HA70	0.89	0.93	HB55	0.90	0.92	4.49	2.22
HA100	0.90	0.94	HB56	0.90	0.92	3.89	2.22
HA1	0.90	0.94	HB72	0.90	0.93	4.44	3.33
HA26	0.91	0.94	HB74	0.90	0.91	3.30	1.11
HA7	0.91	0.95	HB86	0.90	0.92	4.40	2.22
HA38	0.92	0.95	HB95	0.90	0.92	3.26	2.22
HA63	0.92	0.96	HB98	0.90	0.93	4.35	3.33
HA65	0.92	0.96	HB9	0.91	0.94	4.35	3.31
HA88	0.93	0.97	HB44	0.91	0.94	4.30	3.31
HA75	0.93	0.98	HB28	0.91	0.93	5.38	2.20
HA96	0.93	0.99	HB37	0.91	0.94	6.45	2.75
HA3	0.93	1.00	HB51	0.91	0.94	7.53	2.75
HA15	0.93	1.01	HB59	0.91	0.93	8.60	2.20

Households A (HA)			Households B (HB)			HA	HB
Individual	**Income (2000)**	**Income (2004)**	**Individual**	**Income (2000)**	**Income (2004)**	**%ΔHA**	**%ΔHA**
HA57	0.93	1.03	HB17	0.92	0.94	10.75	2.17
HA52	0.94	1.05	HB36	0.92	0.95	12.30	3.26
HA77	0.94	1.08	HB54	0.92	0.96	15.51	4.35
HA59	0.94	1.20	HB100	0.93	0.97	28.34	3.76
HA5	0.94	1.22	HB4	0.94	0.97	29.79	3.19
HA16	0.95	1.25	HB13	0.95	0.98	31.58	3.16
HA11	0.96	1.26	HB76	0.96	0.99	31.25	3.66
HA40	0.99	1.28	HB92	0.96	0.99	29.29	3.13
HA39	1.00	1.28	HB69	0.96	1.00	28.00	4.17
HA29	1.01	1.30	HB94	0.97	1.10	28.71	13.40
HA33	1.02	1.35	HB57	0.97	1.15	32.35	18.56
HA80	1.03	1.36	HB3	0.98	1.20	32.04	22.45
HA62	1.05	1.39	HB33	0.99	1.25	32.38	26.26
HA28	1.10	1.40	HB62	1.00	1.27	27.27	27.00
HA32	1.12	1.45	HB60	1.10	1.28	29.46	16.36
HA87	1.16	1.50	HB46	1.20	1.30	29.31	8.33
HA41	1.19	1.52	HB63	1.30	1.35	27.73	3.85
HA27	1.20	1.56	HB61	1.30	1.38	30.00	6.15
HA24	1.25	1.56	HB15	1.40	1.40	24.80	0.00
HA12	1.30	1.66	HB11	1.40	1.45	27.69	3.57
HA47	1.35	1.70	HB5	1.45	1.45	25.93	0.00
HA64	1.38	1.78	HB38	1.45	1.48	28.99	2.07
HA54	1.40	1.80	HB49	1.50	1.55	28.57	3.33
HA58	1.50	1.85	HB16	1.60	1.80	23.33	12.50
HA44	1.60	2.20	HB45	1.70	1.90	37.50	11.76

Source: *Field Survey, 2004*