Indian Journal of Agricultural Sciences **85** (1): 131–6, January 2015/Article

Mapping and cataloguing of trees of IARI campus, New Delhi, India using GIS and GPS

REZA AHMADZADEH[1], S S SINDHU[2], K V PRASAD[3], D K DAS[4], and R N SAHOO[5]

Indian Agricultural Research Institute New Delhi 110 012

Received: 9 April 2014; Revised accepted: 7 October 2014

ABSTRACT

A GIS-based method for locating potential tree-planting sites and modification based on land cover data is introduced. This study introduces a program for developing green spaces in urban areas through (1) land suitability analysis based on GIS; (2) quantifying green areas based on the microclimate suitability; and (3) applying landscape-ecology principles in organizing green spaces used to evaluate selected benefits provided by the tree canopy. Arc_GIS environment, a computer program was developed for preparation of different maps such as digitizing, road, building, green space and tree map as well as to classify them. Using GPS the existing trees were physically documented (altitude, latitude, botanical name, common name etc.), the data of which is analyzed using Arc-GIS programme. A comprehensive study of 50 tree species was made out of the large number of genera and various species of approximately 3700 across the IARI Campus. Three different maps of road, building and green were prepared based on the study made.

Key words: Building map, Green map, GIS, GPS, Road map, Trees map

The use of tools such as a Geographic Positioning System (GPS) or Geographic Information System (GIS) in developing a municipal tree inventory seems to be gaining popularity thanks to changes in these technologies and reduced costs (Wilson 2004). A survey of arboriculture features in different campuses was collated, to determine the current status of campus tree inventories, and these results were discussed in the context of a tree inventory currently underway in IARI, New Delhi, India. Tree canopy cover is the urban forest's driving force for producing benefits for the community (Nowak *et al*. 2002).

Estimating potential tree canopy cover and identifying potential tree-planting sites is important for expanding the urban forest. Potential and existing canopy cover has been analyzed for several cities (Nowak *et al*. 1996).

Urban trees not only help in controlling heat gain and mitigate urban heat islands (Huang *et al*. 2008). A healthy, vigorous tree canopy is essential to perpetuate the character of the campus landscape and to strive towards a healthy ecosystem. We must protect the healthy trees during construction to sustain the microclimate for comfortable living (Girling *et al*. 2001).

GIS based study of IARI campus, New Delhi, India was made to describe the plant morphology and location along with tree cataloguing. Virtually planted potential trees can be counted and their canopy summed up to project potential canopy cover. This approach provides more realistic estimates of tree planting potential than are obtained using the traditional approach. Therefore, we define potential tree canopy cover as the sum of canopy cover area from all virtually planted trees at maturity. Existing canopy cover refers to the total crown projection area of trees currently within the campus. Keeping in view the above fact, the study was carried out to prepare a green map of selected trees available on roadside, official and residential area in IARI Campus using GIS tool and to develop a quantitative and qualitative catalogue.

In one of the study made by Girling *et al*. 2001, in University of Oregon campus has described tree landscape and management. Although great efforts have been made to preserve existing trees, this is not always possible. Then, it is essential to have policies in place that define how to replace lost trees in a way that will preserve the campus tree canopy as well as preserve the campus's sunny spaces.

The locations of about 200 species of campus trees were indicated on newly-developed tree maps. By clicking on each tree icon, detailed information about that particular species would be shown. Photographs and audio descriptions of flowers on campus were also updated, making it a piece of comprehensive interactive teaching material for green education in Hong Kong. A tree catalogue system was developed to enhance public understanding of trees. Labels detailing tree names and species were tagged to trees with the help of CUHK staff and student (Sung 2010).

[1]Centre for Protected Cultivation Technology (CPCT), [2]e mail: sssindhu2003@yahoo.co.in, [3]Division of Floriculture and Landscaping, [4, 5] Division of Environmental Science

Bartok *et al*. (2000) GPS is a Global Positioning System and it was originally created by the United States Department of Defence at a cost of $16 billion dollars. A constellation of 24 satellites orbit Earth at 18000 km in a pattern that allows for at least four of them to be available from any point on Earth's surface at any given time. Accuracy is generally within 30m but it can be corrected to within a few centimeters. GPS calculates distances by measuring the travel time of a radio message sent from the satellite and then using trigonometry. Three satellites are mainly used for measurement, and the fourth is used to eliminate any timing offset. GPS is used to pin-point the locations of trees for the purpose of mapping.

GPS and GIS are being used for mapping and taking inventory of trees within in an area for the purposes of tree management (Bartok *et al*. 2000). Mapping the trees on campus and thus developing an inventory of them will lead to a more sustainable campus in a number of ways. For example, identifying the species can help to maintain biodiversity by locating the rare species and ensuring that they are not removed. Non-native trees can be identified and in the future they can be removed and replaced with native species if necessary.

MATERIALS AND METHODS

All the trees on major roads, surrounding office and laboratory buildings were catalogued along with their attributes and presented in Table 1.

Coordinates (latitude: longitude) of each tree were measured with the help of GPS (Trimble Juno SC). Each tree was represented as a point on a vector layer prepared in ARC-GIS (version 9.2). Attribute of each tree, like English name, scientific name, family, latitude, altitude, flowering season and leaf falling time was added to the respective points.

The Indian Agricultural Research Institute (IARI) is the country's premier national Institute for agricultural research, education and extension. The present campus of the Institute occupied an area of about 500 hectares. It is located about 8 km west of New Delhi Railway Station and about 16 km north-east of Indira Gandhi International Airport, New Delhi. The location stands at the latitudes between 28.62°N and 28.65°N; longitudes between 77.15°E and 77.17°E; at an average altitude of 228.61 meters above mean sea level. The climate is subtropical semi-arid with dry hot summer and cold winter. May and June are very hot months in which May is the hottest month with monthly mean maximum temperature 39.1°C. Daily maximum temperature reaches above 45.0°C for few days almost every year. The all time high daily maximum temperature (46.8°C) was recorded on May 29, 1998 at the IARI Agromet Observatory. December and January are very cold months in which January is the coldest month with monthly mean minimum temperature 6.5°C. Only in few days during the period of 1980-2010, daily minimum temperature reached sub zero level. The all time low daily minimum temperature (-1.4°C) recorded

Table 1 Cataloguing of tree species in IARI, Campus

Tree species (Botanical name)	Common Name	Family	Height
Ficus religiosa	Peepal	*Moraceae*	18 m
Azadiracta indica	Neem	*Meliaceae*	12 m
Alstonia scholaris	Saptaparni	Apocynaceae	14 m
Ficus infectoria	Pilkhan	*Moraceae*	18 m
Morus alba	Toot	*Moraceae*	9 m
Ficus elastica	India Rubber Tree	*Moraceae*	14 m
Ziziphus mauritiana	Ber	Rhamnaceae	8 m
Lagerstroemia speciosa	Jarul	Lythraceae	8m
Syzigium cumini	Jamun	Myrtaceae	16 m
Punica granatum	Anar	Lythraceae	4 m
Ficus benjamina	Weeping fig	*Moraceae*	12 m
Ficus benghalensis	Banyan	*Moraceae*	15 m
Drypetes roxburghii	Putranjiva	Putranjivaceae	14 m
Polyalthia longifolia	Ashok	Annonaceae	12 m
Mangifera indica	Mango tree	Anacardiaceae	12 m
Terminalia arjuna	Arjun	Combretaceae	24 m
Ficus lyrata	Fiddleleaf fig	*Moraceae*	7 m
Plumeria rubra	Frangipani	Apocynaceae	6 m
Pinus roxburghii	Chir pine	Pinaceae	16 m
Callistemon viminalis	Weeping bottlebrush	Myrtaceae	10 m
Thevetia peruviana	Yellow oleander	Apocynaceae	5 m
Olea europaea	Olive tree	Oleaceae	7 m
Eucalyptus tereticornis	Forest red gum	Myrtaceae	22 m
Bauhinia variegata	Kachnar	Fabaceae	10 m
Cassia fistula	Amaltas	Fabaceae	10 m
Cassia javanica	Java cassia	Fabaceae	8 m
Cassia grandis	Brazilian cassia	Fabaceae	12 m
Millettia peguensis	Moulmein rosewood	Fabaceae	12 m
Dalbergia sissoo	Shisham	Fabaceae	14 m
Fernandoa adenophyllum	Katsagon	Bignoniaceae	15 m
Prosopis juliflora	Vilaiti keekar	Fabaceae	12 m
Albizia lebbeck	Siris	Fabaceae	12 m
Delonix regia	Gulmohur	Fabaceae	10 m
Grevillea robusta	Silky oak	Proteaceae	16 m
Caryota urens	Jaggery palm	Arecaceae	10 m
Roystonea regia	Royal palm	Arecaceae	18 m
Livistonia rotundifolia	Footstool palm	Arecaceae	5 m
Araucaria columnaris	New caledonian pine	Araucariaceae	18 m
Populus deltoides	Eastern cottonwood	Salicaceae	12 m
Cupressus sempervirens	Italian cypress	Cupressaceae	8 m
Ailanthus excelsa	Maharukh	Simaroubaceae	18 m
Citrus × limon	Lemon	Rutaceae	5 m
Psidium guajava	Guava	Myrtaceae	10 m
Poncirus trifoliata	Trifoliate Orange	Rutaceae	8 m
Prunus persica	Peach tree	Rosaceae	4 m
Tabernaemontana divaricata	Chandni	Apocynaceae	2 m
Platycladus orientalis	Morpankhi	Cupressaceae	6 m
Pongamia pinnata	Karanj	Fabaceae	12 m
Tamarix aphylla	Farash	Tamaricaceae	10 m
Mimusops elengi	Maulsari	Sapotaceae	12 m

on January 9, 2006 (Das *et al*. 2009). IARI campus receives around 769 mm of rainfall annually and the major portion (550 mm) is received in the monsoon season (July-September). The normal date of onset of monsoon is June, 29.During winter, a small amount of rainfall (about 63 mm) is received due to western disturbances. Dust storms and squalls visit the campus for few days in every year during the summer months causing damage to the trees of the campus.

RESULTS AND DISCUSSION

The study on detailed mapping of IARI is categorized into 5 sub-groups for preparing geo reference map, road map, building map and green map of selected trees and each of them are discussed in detail as below.

Geo reference map

This Map was digitized at Division of Agricultural Physics, IARI, New Delhi. With the help of Google PRO program a Geo reference map was created. It refers to longitude and latitude of the site. The primary purpose of this Geo reference map is for preparation of other maps like road, building, green and selected tree maps. For preparation of Geo reference Map, Google Earth Map is available in public domain and it has been used to explore as a best map. Google map was downloaded from http:// maps.google.co.in/maps?hl=en&tab=wl for capturing the high resolution picture, and then Geo referencing and mosaic was done, using the image processing software ENVI.

Road Map

Road Map was prepared from the Geo reference IARI Google map using in GIS platform. Road Map that prepared included 3 avenues and 6 streets.

Avenues

There are three avenues and six streets in IARI campus

Avenue No.I : From I.A.R.I main gate (Gate No.1) to WTC cross (1.4 km)

Avenue No.II : From Director's Office to Tennis court (1.0 km).

Avenue No.III: From IARI main gate (Gate No. II) (Inderpuri Gate) to Virology gate (2.6 km).

Streets

Street No.I: From Avenue I to Director's Office square (0.22 km)

Street No.II: IASRI Road to R. Block (0.76 km)

Street No.III: From Grisham hostel to NRL crossing (0.44 km)

Street No. IV: From Varsha Hostel to NRL crossing (0.44 km)

Street No. V: From Pusa Product Cell Centre to Scientists Apartments (1.0 km)

Street No.VI: NBPGR Road start from Agricultural Engineering (0.89 km)

Building map

Building Map was prepared from the Geo reference map of IARI that was prepared form Google map using GIS platform. Building Map that was prepared is classified as official buildings (42 locations) and residential buildings (15 locations).

Green map

Green Map was prepared from the Geo reference map of IARI which was prepared form Google map using in GIS environment. All green areas (all places that are covered with vegetation) were marked in this map. It covers the entire area covered by trees, shrubs, hedges, lawns and other flower beds.

Brief description about the major tree species are given below.

Avenue No.I: *Terminalia arjuna, Polyalthia longifolia, Fernandoa adenophyllum.*

Avenue No.II: *Ficus infectoria,Cassia nodosa, cassia siemea,Ficus lyrata*

Avenue No.III: *Syzigium cumini, Eucalyptus tereticorni, Lagestromea flosreginae, Putranjiva roxburghai.*

The Street were further classified into

Street No.I: *Roystonea regia*, *Polyalthia longifolia, Delonix regia*

Street No.II: *Fernandoa adenophyllum, Ficus religiosa*

Street No.III: *Azadirecta indica, Lagestromea flosreginae, Alstonia scholaris*

Street No.IV: *Pongamia pinnata, Fernandoa adenophyllum, Mangifera indica*

Street No.V: *Millettia peguensis*, *Alstonia scholaris, Lagestromea flosreginae*

Street No.VI: *Plumeria rubra, Morus alba, Prosopis juliflora, Cassia fistula*

Tree map

Tree Map was prepared from the Geo reference map of IARI which was prepared with the help of Google map using GIS environment. Some of the tree species in IARI selected and they marked with GPS for location and plantation potential.

Layer A: Weeping fig *(Ficus benjamina)* (25), Royal palm (*Roystonea regia*) (24), Mango tree (*Mangifera indica*) (8), Putranjiva (*Drypetes roxburghii*) (4), Jaggery palm (*Caryota urens*) (7), India Rubber Tree (*Ficus elastica*) (5), Neem (*Azadirecta indica*) (12), Trifoliate Orange (*Poncirus trifoliata*) (1), Gulmohur (*Delonix regia*) (8), Weeping bottlebrush (*Callistemon viminalis*) (17), Peepal (*Ficus religiosa*) (13), Chandni (*Tabernaemontana divaricata*) (53), Ashok (*Polyalthia longifolia*) (47), Pilkhan (*Ficus infectoria*) (4), Jamun (*Syzigium cumini*) (5), Amaltas (*Cassia fistula*) (27), Morpankhi (*Platycladus orientalis*) (4), Chir pine (*Pinus roxburghii*) (1), Yellow oleander (*Thevetia peruviana*) (3), Banyan (*Ficus banghalensis*) (4), Toot (*Morus alba*) (15), Silky oak (*Grevillea robusta*) (4), Frangipani (*Plumeria rubra*) (13), New caledonian pine (*Araucaria columnaris*) (1), Footstool palm (*Livistonia*

rotundifolia) (2), Vilaiti keekar (*Prosopis juliflora*) (9).

*Layer B***:** Amaltas (*Cassia fistula*) (1), Arjun (*Terminalia arjuna*) (1), Ashok (*Polyalthia longifolia*) (260), Banyan (*Ficus banghalensis*) (4), Brazilian cassia (*Cassia grandis*) (2), Chir pine (*Pinus roxburghii*) (3), Farash (*Tamarix aphylla*) (2), Fiddleleaf fig (*Ficus lyrata*) (2), Footstool palm (*Livistonia rotundifolia*) (2), Forest red gum (*Eucalyptus tereticornis*) (68), Frangipani (*Plumeria rubra*) (71), Guava (*Psidium guajava*) (3), Gulmohur (*Delonix regia*) (3), India Rubber Tree (*Ficus elastica*) (5), Italian cypress (*Cupressus sempervirens*) (4), Jaggery palm (*Caryota urens*) (13), Jamun (*Syzigium cumini*) (8), Jarul (*Lagerstroemia speciosa*) (3), Kachnar (*Bauhinia variegate*) (1), Karanj (*Pongamia pinnata*) (8), Lemon (*Citrus* × *limon*) (6), Maharukh (*Ailanthus excels*) (1), Mango tree (*Mangifera indica*) (22), Neem (*Azadiracta indica*) (14), Peepal (*Ficus religiosa*) (26), Pilkhan (*Ficus infectoria*) (7), Royal palm (*Roystonea regia*) (37), Shisham (*Dalbergia sissoo*) (5), Silky oak (*Grevillea robusta*) (12), Toot (*Morus alba*) (56) Trifoliate Orange (*Poncirus trifoliate*) (1), Weeping bottlebrush (*Callistemon viminalis*) (10), Weeping fig (*Ficus benjamina*) (6).

Layer C: Amaltas (*Cassia fistula*) (48), Arjun (*Terminalia arjuna*) (3), Ashok (*Polyalthia longifolia*) (283), Banyan (*Ficus banghalensis*) (3), Chir pine (*Pinus roxburghii*) (2), Eastern cottonwood (*Populus deltoids*) (2), Footstool palm (*Livistonia rotundifolia*) (10), Forest red gum (*Eucalyptus tereticornis*) (22), Frangipani (*Plumeria rubra*) (16), Guava (*Psidium guajava*) (15), Gulmohur (*Delonix regia*) (56), India Rubber Tree (*Ficus elastica*) (7), Jaggery palm (*Caryota urens*) (2), Jamun (*Syzigium cumini*) (27), Java cassia (*Cassia javanica*) (5), Kachnar (*Bauhinia variegate*) (7), Katsagon (*Fernandoa adenophyllum*) (39), Lemon (*Citrus* × *limon*) (3), Mango tree (*Mangifera indica*) (9), Neem (*Azadiracta indica*) (107), New caledonian pine (*Araucaria columnaris*) (1), Olive tree (*Olea europaea*) (1), Peach tree (*Prunus persica*) (1), Peepal (*Ficus religiosa*) (22), Putranjiva (*Drypetes roxburghii*) (12), Pilkhan (*Ficus infectoria*) (198), Royal palm (*Roystonea regia*) (74), Shisham (*Dalbergia sissoo*) (6), Silky oak (*Grevillea robusta*) (3), Siris (*Albizia lebbeck*) (9), Toot (*Morus alba*) (28), Trifoliate Orange (*Poncirus trifoliate*) (1), Vilaiti keekar (*Prosopis juliflora*) (19), Weeping bottlebrush (*Callistemon viminalis*) (34), Yellow oleander (*Thevetia peruviana*) (3).

Layer D: Amaltas (*Cassia fistula*) (1), Arjun (*Terminalia arjuna*) (195), Ashok (*Polyalthia longifolia*) (99), Forest red gum (*Eucalyptus tereticornis*) (99), Jamun (*Syzigium cumini*) (360), Jarul (*Lagerstroemia speciosa*) (14), Katsagon (*Fernandoa adenophyllum*) (117), Peepal (*Ficus religiosa*) (3), Pilkhan (*Ficus infectoria*) (1), Putranjiva (*Drypetes roxburghii*) (100), Shisham (*Dalbergia sissoo*) (10), Toot (*Morus alba*) (4), Vilaiti keekar (*Prosopis juliflora*) (2), Weeping fig (*Ficus benjamina*) (14).

*Layer E***:** Amaltas (*Cassia fistula*) (12), Ashok (*Polyalthia longifolia*) (11), Banyan (*Ficus banghalensis*) (3), Farash (*Tamarix aphylla*) (9), Forest red gum (*Eucalyptus tereticornis*) (38), Frangipani (*Plumeria rubra*) (11), Guava (*Psidium guajava*) (6), Gulmohur (*Delonix regia*) (1), India rubber tree (*Ficus elastica*) (2), Jaggery palm (*Caryota urens*) (2), Jamun (*Syzigium cumini*) (16), Kachnar (*Bauhinia variegate*) (7), Karanj (*Pongamia pinnata*) (36), Katsagon (*Fernandoa adenophyllum*) (40), Lemon (*Citrus* × *limon*) (13), Mango tree (*Mangifera indica*) (37), Moulmein rosewood (*Millettia peguensis*) (50), Neem (*Azadirecta indica*) (7), Peepal (*Ficus religiosa*) (12), Pilkhan (*Ficus infectoria*) (8), Putranjiva (*Drypetes roxburghii*) (33), Saptaparni (*Alstonia scholaris*) (12), Shisham (*Dalbergia sissoo*) (5), Silky oak (*Grevillea robusta*) (57), Toot (*Morus alba*) (3), Vilaiti keekar (*Prosopis juliflora*) (5), Weeping bottlebrush (*Callistemon viminalis*) (12), Yellow oleander (*Thevetia peruviana*) (3).

*Layer F***:** Among this five trees species (*Ficus religiosa*, *Azadiracta indica*, *Alstonia scholaris*, *Ficus infectoria* and *Morus alba*) with four replication, totally 20 tree species were selected for the experiments.

Cataloguing tree species in IARI Campus

During the course of investigation 3700 trees that belonged to 50 different species were cataloged. Out of the 50 species (Table 1), *Alstonia scholaris, Ficus elastica, Syzigium cumini, Ficus benjamina, Ficus banghalensis, Drypetes roxburghii, Polyalthia longifolia, Ficus lyrata, Callistemon viminalis, Thevetia peruviana, Olea europaea, Eucalyptus tereticornis, Caryota urens, Roystonea regia, Livistona rotundifolia, Araucaria columnaris, Cupressus sempervirens, Citrus* × *limon, Psidium guajava*, *Poncirus trifoliate, Tabernaemontana divaricata, Platycladus orientalis, Tamarix aphylla, Mimusops elengi,* are evergreen, *Ficus religiosa, Ficus infectoria, Morus alba, Ziziphus mauritiana, Lagerstroemia speciosa, Punica granatum, Terminalia arjuna, Plumeria rubra, Bauhinia variegate, Cassia fistula, Cassia javanica, Cassia grandis, Millettia peguensis, Dalbergia sissoo, Fernandoa adenophyllum, Prosopis juliflora, Albizia lebbeck, Delonix regia, Populus deltoids, Ailanthus excelsa, Prunus persica, Pongamia pinnata,* are deciduous, *Azadiracta indica, Pinus roxburghii,*are semi deciduous and *Mangifera indica, Grevillea robusta,* are semi-evergreen.

Out of the 50 species *Ficus religiosa, Ficus infectoria, Morus alba, Ficus elastica, Ficus benjamina, Ficus banghalensis, Ficus lyrata,* belong to *Moraceae* family. *Azadirecta indica* belong to *Meliaceae* family. *Alstonia scholaris, Plumeria rubra, Thevetia peruviana, Tabernaemontana divaricata,* belongs to Apocynaceae family. *Ziziphus mauritiana* belong to Rhamnaceae family. *Lagerstroemia speciosa, Punica granatum,* belongs to Lythraceae family. *Syzigium cumini, Callistemon viminalis, Eucalyptus tereticornis, Psidium guajava*, belongs to Myrtaceae family. *Drypetes roxburghii* belong to Putranjivaceae family. *Polyalthia longifolia* belong to Annonaceae family. *Mangifera indica* belong to Anacardiaceae family. *Terminalia arjuna* belong to Combretaceae family. *Pinus roxburghii* belong to Pinaceae

family. *Olea europaea* belong to Oleaceae family. *Bauhinia variegate, Cassia fistula, Cassia javanica, Cassia grandis, Millettia peguensis, Dalbergia sissoo, Prosopis juliflora, Albizia lebbeck, Delonix regia, Pongamia pinnata,* belong to Fabaceae family. *Fernandoa adenophyllum* belong to Bignoniaceae family. *Grevillea robusta* belong to Proteaceae family. *Caryota urens, Roystonea regia, Livistonia rotundifolia,* belongs to Arecaceae family. *Araucaria columnaris* belong to Araucariaceae family. *Populus deltoids* belong to Salicaceae family. *Cupressus sempervirens, Platycladus orientalis* belong to Cupressaceae family. *Ailanthus excels* belong to Simaroubaceae family. *Citrus × limon, Poncirus trifoliate,* belong to Rutaceae family. *Prunus persica,* belong to Rosaceae family. *Tamarix aphylla,* belong to Tamaricaceae family. *Mimusops elengi* belong to Sapotaceae family.

The trees are of various heights some are of short stature, *Punica granatum, Ficus lyrata, Plumeria rubra, Thevetia peruviana, Olea europaea, Livistona rotundifolia, Citrus × limon, Prunus persica, Tabernaemontana divaricata, Platycladus orientalis* and some of long stature, *Ficus religiosa , Alstonia scholaris , Ficus infectoria , Ficus elastica, Syzigium cumini, Ficus banghalensis, Drypetes roxburghii, Terminalia arjuna, Pinus roxburghii, Eucalyptus tereticornis, Dalbergia sissoo, Fernandoa adenophyllum, Grevillea robusta, Roystonea regia, Araucaria columnaris, Ailanthus excelsa* and some are of medium stature, *Azadiracta indica, Morus alba, Ziziphus mauritiana, Lagerstroemia speciosa, Ficus benjamina, Polyalthia longifolia, Mangifera indica, Callistemon viminalis, Bauhinia variegate, Cassia fistula, Cassia javanica, Cassia grandis, Millettia peguensis, Prosopis juliflora, Albizia lebbeck, Delonix regia, Caryota urens, Populus deltoids, Cupressus sempervirens, Psidium guajava, Poncirus trifoliate, Pongamia pinnata, Tamarix aphylla, Mimusops elengi* were studied.

All important tree species, except five selected tree species namely *Ficus religiosa*, *Azadirecta indica*, *Alstonia scholaris*, *Ficus infectoria* and *Morus alba* were selected as experimental trees (Fig 3). The other tree species were Weeping bottlebrush (*Callistemon viminalis*) (74), Royal palm (*Roystonea regia*) (135), Katsagon (*Fernandoa adenophyllum*) (190), Jamun (*Syzigium cumini*) (416), Forest red gum (*Eucalyptus tereticornis*) (236), Ashok (*Polyalthia longifolia*) (696), Arjun (*Terminalia arjuna*) (149).

Flowering tree species exist in IARI Campus

All important flowering tree species are identified, Tree species are; Amaltas (*Cassia fistula*) (115), Frangipani (*Plumeria rubra*) (93), Gulmohur (*Delonix regia*) (69), Jarul (*Lagerstroemia speciosa*) (28), Moulmein rosewood (*Millettia peguensis*) (50), Weeping bottlebrush (*Callistemon viminalis*) (71), Yellow oleander (*Thevetia peruviana*) (42).

A perusal of the different maps (viz. green map, road map, building map and tree map) and cataloguing of trees indicated that it is possible to use GPS and Arc GIS to pin point the extent of vegetation mostly trees and shrubs in a defined area. It is evident from the map that it is possible to identify the trees and shrubs by harmonizing the data collected by GPS and incorporating the data in Arc GIS platform. An effort was made in this study to document all the trees in each avenue, street, residential, office building and green area and catalogued the data in the form of a database.

The cataloguing refers to the trees species presently existing on the road side, surroundings of buildings and on green area. From this study, we can also explore the possibility of identifying the gaps in the plantations and also identify open areas that are suitable for re-plantation. As and when there is tree damage in the campus either we must replace the tree with the same plant species or if needed native trees must be considered that have good canopy and better living index for the human beings. In our study we could catalogue 3700 trees belonging to 50 species of trees by using GPS and ARC-GIS and it is possible to retrieve the database by clicking on each tree icon. On clicking the information that is available include common name, botanical name, family, altitude, latitude and plant height. In a similar study by Sung *et al* 2010 at China University of Hong Kong reported that about 200 species of campus trees were catalogued and the database is user friendly. By clicking on each tree icon, detailed information about that particular species will be shown. Photographs and audio descriptions of flowers on campus are also updated, making it a piece of comprehensive interactive teaching material for green education in Hong Kong. A tree catalogue system was developed to enhance public understanding of trees. Although there has been considerable interest in the rejuvenation and greening of IARI Campus recent studies on the behavioral and environmental impacts of green space, particularly tree cover, suggest that green space on campus may be more important than previously understood. However, little is known about the conditions and land cover of IARI Campus. To understand the structure of the land cover on campus, this study used Geographic Information System (GIS) software to classify and compare land cover. The trees on IARI campus are unique and significantly contribute to the local ecosystems. Therefore, development will preserve and protect existing trees to the maximum extent possible and plan for continued enhancement of the plantation in the campus. In order to define the desired tree canopy and management approach, one must consider the full range of benefits trees provide to the campus-aesthetic, environmental, educational, historical, and psychological. (Girling *et al.* 2001). An adaptation strategy that has been proposed is to 'green' urban areas, essentially by increasing the abundance and cover of vegetation (Givoni 1991, Gill *et al.* 2007). Vegetation and urban materials differ in moisture, aerodynamic and thermal properties, and so urban greening could affect temperatures through different processes.

A green map that is generated during the investigations indicated that the map provides the information regarding

the green cover in the campus. The road map indicated the details of road in terms of its length and road side avenue trees. The building map indicates the green cover around the buildings, location of the building which would be helpful for the students to understand campus and local environmental problems. Similar findings were reported by Heinz during 1995.

Many cities around the world are experiencing the negative effects associated with none sustaining and insufficient level of tree canopy coverage. Trees and tree canopy play a crucial role in the environment, providing benefits such as clean water, air, climate control and sustained ecological resources and native species habitat (Scott *et al*, 1999). Additionally, tree and tree canopy play an important role to enhance real estate value through improving ambiance and local environment.

REFERENCES

Bartok N, Farassoglou C, Sutic N. 2000. Mapping Trees at UW Using GPS. University of Washington, ERS 285, July 20.

Gill S, Handley J, Ennos R, Pauleit S. 2007. Adapting cities for climate change: the role of the green infrastructure. *Building and Environment* **30**: 97–115.

Girling C, Blume G, Daly C, Deshpande N, Grzybowski J, McGowen R, Melnick R, Selker E, Strip G, Tublitz N and Westrick M. 2001. University of Oregon Campus Tree Plan.

Givoni B. 1991. Impact of planted areas on urban environmental quality: a review. *Atmos. Environ* **25**: 289–99.

Heinz T. 1995. Blueprint for a Green Campus: The Campus Earth Summit Initiatives for Higher Education. A project of the heinz family foundation.

Huang L. 2008. A fieldwork study on the diurnal changes of urban microclimate in four types of ground cover and urban heat island of Nanjing, China. *Building and Environment* **43**(2008): 7–17.

McCurley-Stafford L. 2002. The drought of 2002 in Boulder County, Colorado. Retrieved May 15, 2006, from http://www.surf.salford.ac.uk/documents/UrbanVulnerability/McCurley-Stafford.pdf

Nowak D J and Crane D E. 2002. Carbon storage and sequestration by urban trees in the USA. *Environnemental Pollution* **116**: 381–9.

Nowak D J, Rowntree R A, McPherson E G, Sisinni S M, Kerkmann E R and Stevens J C. 1996. Measuring and analyzing urban tree cover. *Landscape and Urban Planning* **36**: 49–57.

Scott K I, Simpson J R and McPherson G. 1999. Effects of tree cover on parking lot microclimate and vehicle emissions. *Journal of Arboriculture* **25**(3): May 1999.

Sung J Y, Tang-wah E Y, Ho A, Tung F, Shiu-ying H. and Lee-man C. 2010. CUHK Tree Project. The Chinese University of Hong Kong.

Wilson I 2004. GPS / GIS Tools and Tree Inventory. Urban Forestry Supervisor City of Kelowna.