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Jack Kimmel International Grant Application

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Applicant

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Degrees	1. PhD in Plant Sciences from the University of Manchester, UK in 2013. 2.Double Degree MSc in Sustainable Tropical Forestry (SUTROFOR) from the University of Wales, Bangor, UK in 2009 and from the Technical University of Dresden, Germany in 2008. 3. MSc in Forestry from the University of Chittagong, Bangladesh in 2007 4. B.Sc (Honours) in Forestry from the University of Chittagong, Bangladesh in 2005
Relevant citations authored	1.Ennos, A.R., Armson, D., Rahman, M.A., 2015. How Useful are Urban Trees? The Lessons of the Manchester Research Project. Johnston, M. and Percival, G. eds. Trees, people and the built environment II. Institute of Chartered Foresters, Edinburgh: 62-70. 2.Bolton, C., Rahman, M.A., Armson, D., Ennos, A.R, 2014. Effectiveness of an Ivy Covering at Insulating a Building against the Cold in Manchester, U.K: A Preliminary Investigation. Building and Environment, 80: 32-35. 3. Rahman, M.A, Armson, D., Ennos, A.R, 2014. Effect of urbanization and climate change in the rooting zone on the growth and physiology of Pyrus calleryana. Urban Forestry & Urban Greening, 13 (2): 325–335. 4. Rahman, M.A., Armson, D., Ennos, A.R, 2014. A comparison of the growth and cooling effectiveness of five commonly planted urban tree species. Urban Ecosystems, DOI 10.1007/s11252-014-0407-7. 5.Rahman, M.A., Stringer, P., Ennos, A.R, 2013. Effect of pit design and soil composition on performance of Pyrus calleryana street trees in the establishment period. Arboriculture & Urban Forestry, 39(6): 256–266. 6. Gill, S.E., Rahman, M.A., Handley, J. F., Ennos, A.R., 2013. Modelling water stress to urban amenity grass in Manchester UK under climate change and its potential impacts in reducing urban cooling. Urban Forestry & Urban Greening, 12(3): 350-358. 7. Armson, D., Rahman, M.A., Ennos, A.R., 2013. A Comparison of the Shading Effectiveness of Five Different Street Tree Species in Manchester, UK. Arboriculture & Urban Forestry, 39(4): 157-164. 8. Rahman, M.A., Smith, J.G., Stringer, P., Ennos, A.R., 2011. Effect of rooting conditions on the growth and cooling ability of Pyrus calleryana. Urban Forestry & Urban Greening, 10(3): 185-192. 9. Rahman, M.A., Ennos, A.R. What we know and don't know about the cooling benefits of urban trees (Under Review). 10. Rahman, M.A., Ennos, A.R. What we know and don't know about the carbon storage and sequestration of urban trees (Under Review). 11. Rahman, M.A., Ennos, A.R. What we know and don't know about the surface runoff reduction potential of urban trees (Under Review).
Has this investigator previously received funding from the TREE Fund?	No

If yes, was the funding for this project?

Previous TREE Fund awards

Co-Principal Investigator (if applicable)

Prefix

First name

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Status

Title

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Country

Email address

Phone number

Degrees

Relevant citations authored

Has this investigator previously received funding from the TREE Fund?

If yes, was the funding for this project?

Previous TREE Fund awards

Students/Interns (if applicable)

Student/Intern 1

Name

Department or major

Status

Student/Intern 2

Name

Department or major

Status

Student/Intern 3

Name

Department or major

Status

Project

Project title	Quantifying the cooling effectiveness of urban street trees in relation to their growth
Research area	Root and soil management Urban forestry
Project summary	It is often claimed that planting trees can cool our cities and therefore improve the thermal comfort for the city dwellers. However, urban cooling provided by trees is rarely quantified. The proposed study will investigate 20 trees of two different species and types of urban street canyons in terms of cooling effectiveness (evapotransporative and shade) and tree growth rate. The study will be carried out in the very centre of the Bavarian capital Munich, Germany; a representation of large conurbation. Continuous measurements of sapflux density, soil moisture potential and stem variations along with the periodical measurements of surface temperature and crown variables as well as tree core data over the summer, 2016 will help us to validate the relationship between carbon gain and water relations. Initial setup and instrumentation is mostly available from an ongoing project funded by the Alexander-von-Humboldt foundation. The applied research grant will be used to purchase some more equipment to test the proportional relationship of urban tree growth with their cooling benefits. The results will be incorporated into ecophysiological models that are developed in collaboration with experts at the Technical University of Munich. The expected relationship might help to determine the cooling benefits of the current stock of trees on the selected sites. The potential for upscaling of this ecosystem service on the basis of micro-meteorological models and data from urban forest inventory will also be explored.
Statement of problem	The majority of people in today's world are already living in urban areas. Ongoing urbanization and the expansion of urban areas strongly alter ecological processes. The increase of air temperatures within urban areas compared to their rural surroundings (urban heat island effect - UHI) can cause heat stress and thus negatively affect human well-being and health. Increasing occurrence and intensity of

climatic extremes caused by climate change will exacerbate the problem. The extreme summer of 2003 which is reported to have caused more than 70,000 deaths in excess (according to EU Community Action Programme report for Public Health) and the prolonged heat waves of 2015 in Europe are indicative of the challenges that lie ahead. Urban greenspaces can make cool cities both locally and regionally and thus make an important contribution to their adaptation to climate change.

The urban forest, i.e. the stock of trees in urban areas, is of particular importance for cooling urban areas. Even a small street tree can modify the microclimate by altering the incoming radiation by shading and evapotranspiration. Our previous research have shown that street trees can shade around 30%–50% more than their actual canopy area even at midday - so their influence, unlike that of areas of grass or other herbs, extends outside their canopy. Moreover, with higher reflectivity compared to built surfaces, trees can reduce up to 90% of the incoming radiation to the ground and indirectly reduce the heat storage to reradiate at night to have direct impact on night time UHI. Finally, street trees convert a large amount of solar irradiation into latent heat by evapotranspiration (previous research has shown the range between 36% and 77%). However, the cooling benefits of urban street trees have rarely been quantified in field studies since it is challenging to take continuous measurements in urban environments. Generally, cooling ability of trees depends on their size, vigour, canopy characteristics apart from some other obvious factors such as growth conditions, species difference and placement. For evapotranspirative cooling it is important to know plant hydraulic conductance which is proportionally constant between transpiration from leaves and the water potential difference between the soil and the leaf. Plant hydraulic conductance is closely related to carbon gain and growth; these in turn influence the amount and depth of shade that trees can produce. Therefore, establishing the relationships between water conductance and growth will help us to estimate the cooling ability of urban trees. However, the theory needs to be tested and models need to be calibrated for isolated urban street trees by carrying out experimental studies in which the growth rates are sequentially measured, and related to water loss. The model would allow calculating the cooling efficiency of urban trees simply from the tree growth data. This will help to solve the energy balance equation and can be used on sequential upscaling of three-level hierarchy of the lengthy avenues based on their spatial extent.

Significance of your proposed project as it relates to the profession of arboriculture or urban forestry	UHI abatement is of great significance for developing climate resilient, sustainable and healthy urban environments. Urban forestry and urban arboriculture can make an important contribution to achieving these aims. Numerous studies either empirically or theoretically showed the importance of urban greenspaces in terms of UHI reductions. The proposed study will help to establish reliable equations between cooling ability of trees and growth along with soil and atmospheric variables which can be readily used predicting the potential impact of the urban trees on urban microclimates. This will lead to further investigation on other tree species on different growth conditions to possible validation of results from growth and micro-

meteorological models or from eddy-covariance analysis. Moreover, the expected output of the study will give some insights towards the factors related to the growth of urban trees in street canyons and how single or multiple environmental factors affect the key environmental services provided by them. Therefore, results from this study will support arboriculturists in the targeted selection of appropriate tree species to tolerate urban harsh growing conditions and provide ecosystem services. Moreover, site and species specific recommendations as well as management directives such as for tree location and tree pruning can be evaluated to determine effect on the overall micro-climatic amelioration. The project may help arboriculturists also to incorporate different stakeholders since they will be able to estimate ecosystem services such as local cooling effect or surface runoff reduction potential (from water consumption capacity) by investigating simple growth parameters.

Description of what is currently known about proposed project area	Local cooling effects of trees are mainly due to shading and evapotranspiration. A person under a tree shade feels cooler than a person in the sun . Several experimental as well as modelling studies using micrometeorological models (e.g. RayMan, ENVI-met, Green CTTC) [2-3] have shown significant effect of street trees on improving the thermal comfort for human in urban street canyons across a range of climate zones. Moreover, buildings receive less solar radiation due to tree shade; lower surface temperatures reduce the internal energy demand for cooling. This area has been well researched both empirically and by using models [e.g.4] in North America and it has led to the development of readily usable models such as i-Tree eco and i-Tree streets. However, direct cooling effect of trees by evapotranspiration have not been taken into account in these models. Unfortunately, cooling effects of street treets cannot be simply measured using air temperature. This is problematic since warm air can be readily advected into parks and the cool air from parks into the surrounding streets. Based on a meta-analysis, Bowler et al. concluded that parks had on average a daytime temperature only 0.94 °C cooler than the surrounding urban temperature. Alternatively, surface temperatures have been used. A study in Basel, Switzerland, showed that at midday on a hot summer's day, built surfaces were 12–35 °C warmer than air, whereas the surface temperature of tree leaves was between 1 °C cooler and 4 °C warmer than air temperature . However, the use of the surface temperatures in models is problematic because leaf temperature is dependent on anatomical, physical and physiological factors , while many such models assume that all vegetation performs in the same way and that their effect is merely proportional to their surface cover . However, making direct measurements on trees in an urban ecosystem also presents numerous technical and logistical challenges. Measuring the water loss from trees can be calculated by the mass flow of evapotranspiration (E) and its energy equivalent, the latent heat flow (LE) and it seems to be the most feasible option for urban street trees. However, using the energy balance equation or the Penman-Monteith model of evapotranspiration water losses from urban trees are usually modelled simply by assuming that they

behave like pasture grass . Similarly, the Bowen ratio-energy balance or eddy covariance methods are used to determine heat fluxes of different areas . Few researchers [10-11] have attempted to calculate the ration of latent heat flux to sensible heat flux of a single tree by estimating the latent heat flow. Some others [11-13] have also investigated the amount of water loss from a range of urban trees to know the transpiration rate in different growing conditions. Yet, different urban land uses affect the uptake or release of energy by sensible and latent heat fluxes . Our recent studies have shown that the latent heat flow from individual street trees varies significantly depending on the species and growth conditions [12-13]. Therefore, it is very important to obtain site and species specific empirical data of street trees to be used in models for more precise parameterization of their urban cooling effect.

Considering isolated urban street trees, the easiest way for collecting data on evapotranspiration would be to measure water loss using a lysimeter, but this method can only be used for grass or for small trees in pots. Another approach would be point measurements using porometers. However, porometers only take a snapshot of water loss and the results they give are difficult to scale up to the level of the whole tree. Despite the logistic support it needs and its vulnerability to vandalism, sapflow measurements seems to be most feasible option to determine continuous water loss from urban street trees . The continuous recording of water loss by sap flow measurements can provide us with important information since a decrease in plant hydraulic conductance can lead to the decrease in photosynthetic assimilation rate; a decrease in cell turgor and consequently cell volume growth rate . Vertessy, R.A. et al. showed that the growth rate of a tree, as measured by its dbh increment, can explain almost 88% of the variation in mean daily spring transpiration while investigating the relationships between stem diameter, sapwood area, leaf area and transpiration of 15-year-old Eucalyptus regnans trees. Theoretically, the rate of evapotranspiration will be directly proportional to the rate at which CO_2 enters the stomata and the water use efficiency (WUE) of photosynthesis in conventionally photosynthesising C3 plants can be given by the equation:

$$WUE = 1.6c\ Pa / (e^*L - e)$$

. Here Pa is the ambient concentration of CO_2 in the atmosphere, c is 1 minus the ratio of internal to external CO_2 concentration ((1 – Pi /Pa), e*L is the saturation vapour pressure at leaf temperature and e is the vapour pressure of the atmosphere. Inverting the equations it is possible to find out the water loss hence cooling effect of trees. The validation of this theory for urban street trees is possible if we can correlate the water loss with tree growth rates.

Compared to the measurement of cooling from urban street trees, measurements of growth and morphological attributes are much simpler and well established field methods can be easily adopted. For instance, terrestrial laser scanning (TLS) is widely utilized for high precision measurements to reliably measure crown parameters at the branch level and the software based manual skeletonization method for TLS point clouds has shown great potential for individual tree parameters including tree height, crown diameters and green volume. Additionally, tree core samples can give important information regarding the annual growth traits and a retrospective view of the long-term relations of urban trees to climate to better understand the current tree hydrological state. These insights can also be used for ecophysiological growth models under future conditions of climate change. Moreover, along with diurnal growth patterns dendrometers can also provide specific information on relative stem water content with high temporal resolution since these dimensional changes are directly related to the diurnal dynamics of water storage depletion and replenishment in elastic stem tissues . Therefore, simultaneous measurements of sapflow and stem radius variations using dendrometers might allow us for a better understanding of the functional relationship between tree growth and tree water balances.

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Summary of project goals	The overall aim of the project is to quantify the cooling ability of urban street trees and test the theory that the cooling capacity of urban trees can be estimated from their growth rate. Although there is reasonable agreement between growth and cooling capacity of trees, it is important to validate it through experimental results and modelling. In collaboration with experts from the Chair of Forest Growth and Yield Science of the Technical University of Munich, results will be compared with the newly developed eco-physiological tree growth model “BalanceCity”. Moreover, obtaining an empirical evidence base might provide significant advancement to climate change mitigation and adaptation strategies since there is a big potential of sequential upscaling of the level of investigation from limited spaces between urban canyons to lengthy avenues. This may further lead to using Geographical Information System data extract from vector databases and then analyze their local and averaged characteristics. Although, the study will be limited to two tree species, they have been chosen to represent shade tolerant species and light demanding species. Moreover, the project proposes a generic approach which is transferable to other tree species with similar growth characteristics. Finally, the proposed field guide to measure growth rate and to relate to the cooling effectiveness will help to obtain a more authenticated database to compare with regional scale models. Additionally, assumed regression equation will also be used to compare with the outputs from generic models such as i-tree, i-street developed by USDA Forest Service.
Description of measurable outcomes expected	Initial findings from our ongoing study and assuming the results of these two studies support the theory that the cooling benefits of a tree are directly proportional to its growth rate; the implications are profound. The study will result in: 1. Data on the cooling capacity of two tree species in street canyon conditions in terms of per unit area and also per tree basis. 2. Data on canopy characteristics, diurnal stem variations and

growth and the potential relationship with soil water content and atmospheric variables.

3. Integrating the study results with the past events from dendrochronological analysis of growth rings and comparing the air temperature gradients within a street canyon condition with the simulation results of a process based models “BALANCE” will lead to the development of new model on the relationship between growth and cooling capacity of urban street trees.

4. Developing growth models for urban trees and relating it to their environmental performance, the project will help urban planners to predict the development of size and environmental performance as a function of both current and future climate conditions and to transfer from the single tree on all stocks. Multiplier effects of the project will be supported by:

I. Publications (at least 2 papers addressing the 2 objectives) in journals of academic repute;

II. Establishing links between academics and practitioners;

III. Sharing results among peers through public seminars, symposiums and workshops;

IV. Publication of a practitioner’s guide to describe field inventory methods and relate them to ecosystem services.

Project plan including design, hypotheses, methodology and analyses

Study site and perspective

The project “Quantifying the effect of trees in reducing temperature and air pollution in different urban street canyons” awarded by Alexander von Humboldt Foundation to the author of this proposal has already been started investigating street trees in the city centre of Munich, Germany from April, 2015. The Bavarian capital Munich, representative of a large conurbation in Germany, was chosen as the case study site. In the first stage of the research, we have selected 10 mature lime (Tilia cordata) streets trees in two contrasting urban squares (temporal and spatial) namely Bordeaux Platz and Pariser platz; one well-greened with a more open street canyon (symmetrical street) while the other one with a more closed street canyon (a public square with 8 connecting roads) and a high proportion of water impervious surfaces. In these two plots we have already installed 14 thermal dissipation sapflow sensors (TDP), 10 D 20 Radius Dendrometer (type DR) with Campbell dataloggers (CR800) (Ecomatick, Munich, Germany), 22 soil metric water potential sensors (Tensiomark pF0 – pF7), two separate weather stations for measuring incoming radiation (Global radiation sensor CMP3), photosynthetically active radiation (PQS1 PAR Quantum Sensor), wind speed and direction, rainfall, air temperature and pressure, relative humidity (MeteoMS multi sensor) (Ecotech, Bonn, Germany) and 22 automatic temperature loggers (Measurement System Limited, Berkshire, UK) in 6 different tree canopies at four different depths. The initial results of our study suggested a strong correlation between water loss and stem diurnal variation which is regulated strongly with the atmospheric variables and soil moisture gradients. The relationship revealed sap flow as functional to the change in stem radius increment over time:

$$\text{Sap Flow} = f(\Delta R/\Delta T),$$

where R is radius increment and T is time

However, to specifically answer the questions related to cooling effect of urban street trees and growth we need to investigate at least one more species with contrasting growth characteristics. Therefore, we propose another popular urban street tree with contrasting growth characteristics, black locust (Robinia pseudoacacia), in close vicinity of our first project to investigate transpiration water loss, soil moisture metric potential and continuous stem growth. T. cordata and R. pseudoacacia are proposed since they are among the most widely planted urban street tree species in respect to their habitat and their ecological characteristics (which differ significantly). Considering all these factors, the following hypotheses are formulated for the proposed project:

i. H0: Street trees of different species have no positive impact on reducing the surrounding temperature.

ii. H0: There is a non-linear relationship between urban street tree growth rate and cooling effectiveness even when atmospheric variables and soil moisture gradients are explicit.

The overall aim of this proposed project is to quantify the amount of cooling urban trees can provide in different street canyons and to what extent this ecosystem service is related to tree growth. In particular we have two main research objectives:

i. To quantify the evapotranspirative cooling effect of two different tree species in two contrasting street canyons.

ii. To investigate the relationship between growth and cooling effectiveness provided by urban street trees.

1. Measuring the transpirational water loss

Similar to the earlier project two contrasting street canyon sites will be selected with 10 R. pseudoacacia trees. Each tree will be installed with 2-cm-long, TDP sensors. The sensors will be installed at around 4 m height from the ground to reduce the risk of vandalism but later will be converted to breast height values according to standard method. To take into account of radial differences; three 4 cm and three 6 cm TDP sensors will be installed in three trees. Instantaneous sap flux density (Js g cm-2 s-1), will be continuously measured using thermal dissipation probes throughout the summer, 2016. These outputs will be converted to sap flux density (Js) in the sapwood according to the empirical formula (equation 1):

$$Js = 0.0119 (Tm - T)^{1.231}/T \quad (1)$$

where Tm and T are the temperature differences of heated and unheated needles at no flow and positive xylem flow conditions, respectively. The temperatures will be continuously scanned at 10s interval and the average of every five minute will be stored in data loggers. The whole tree transpiration will be calculated utilizing the algorithms to estimate whole tree transpiration according to equation 2

$$ET=\sum_{i=1}^{n} J_i A_i/1000 \quad (2)$$

where ET is the total daily tree transpiration (kg d-1), n is the number

of 2\4\6 cm increments in
sapwood depth, and Ji and Ai are the sap flux density (g cm-2 d-1) and sapwood area (cm2), respectively, at depth i.

2. Measuring the shading effect
As described earlier and also shown in our previous study that the air temperature under the tree shade or outside does not vary significantly, only the surface temperature of the shaded area will be monitored using a temperature infrared gun (PTD 1, Bosch, Germany) (3 points for each tree canopy for 3 times of the day since the shade will shift) on top of the soil/pavement surface periodically throughout the summer 2016. The cooling benefit from evapotranspiration and shading will be combined into a single unit (W/m2). The result of these values will be regressed with morphological variables and functionality of transpiration cooling ability of those trees.

3. Measuring stem diameter variations
At 4 m height just below the radiation shield of sap flow sensors, 10 D 20 Radius Dendrometer will be installed and also connected to the CR800 dataloggers.

4. Soil and atmospheric data
22 soil tensiomarks will be installed around the dripline of the crown (depending on permission by the city council) at a depth of 30 cm. At two sites two "MeteoMS" multi sensors for wind, temperature, humidity, barometer, rain and two PAR Quantum Sensor and Global radiation sensor CMP3 will be installed to investigate the full soil-plant-atmospheric continuum.

5. Measuring sapwood area and studying growth rings
At the end of the investigation period (end of summer, 2016) each tree will be cored using a tree auger up to the centre. Sapwood depth will be examined from the core samples using a colouring dye. Moreover, samples will be used to study the growth patterns in the past and the present and relate to the cooling effectiveness. Number and width of tree-rings will be measured using a Lintab measurement table (Rinntech). Each individual ring-width chronology will be cross-dated by skeleton plotting involving the visual inspection of core samples and the chosen master chronology, according to marker year’s corresponding to marker rings following the standard practice.

6. Canopy measurements
Laser data sets will be acquired for 10 trees in a near windless condition. A 3D-Laser Mirror Scanner LMS-Z360 (Riegl Company, Austria) will be used which is a surface imaging system based on accurate distance measurement by means of time-of-flight measurement of short infrared laser pulses. For each tree, two scans will be captured on opposite positions and two range images, A and A+B, will be created as cylindrical projections of two data sets, respectively. Leaf area density and volume will be derived according to the method described by P. Huang and H. Pretzsch of Forest Growth and Yield Science chair at the Technical University of

Munich (TUM). Leaf area index (LAI) will also be measured using a hemisphere camera to compare against the product of the mean LAI and the crown volume estimated using the terrestrial laser scanning (TLS).

Data analysis

All data will be collected periodically. Dendroecological data from tree cores and stem variation data from dendrometers will be standardised and tree ring data will be further processed by fitting to a cubic spline corresponding to third degree polynomials to eliminate the signals affecting tree growth at the decennial scale before using for statistical analysis. All ecophysiological and growth data will be analysed using R programming software (R 3.2.1). Data will be subjected to ANOVA and Tukey post-hoc tests when normally distributed, and to Kruskall-Wallis and Wilcoxon-Mann-Whitney tests otherwise to test the significance between sites and species. Cooling benefit will be subjected to multiple regression analysis using stem variations and other weather and soil data as parameters. Moreover, attempts will be made to validate newly developed ecophysiological tree growth model "BalanceCity" (developed by Thomas Rötzer, Michael Leuchner and Angela J. Nunn) with experts at the Forest Growth and Yield Science chair of the Technical University of Munich.

Time schedule

The proposed duration of the project is 12 months between February, 2016 and January, 2017 The following Gantt chart summarizes the plan of activities and intended milestones during the proposed project.

Months
Activity 1 2 3 4 5 6 7 8 9 10 11 12
Literature review on cooling * *
benefits and growth and
physiological modelling
Framework development for * *
site selection and purchasing equipment
Instrumental set * * up
Tree morphological * * * * * measurements
Data * * * * collection
Data analysis and model * * * * development
Research paper * * * * writing
Preparation of practitioner's guide * * * *
book and dissemination of results

Description of plan for disseminating the results of this project

Dissemination and linking academics with the practitioners is central to the success of the proposed project. The project aims to address an issue relating to the UHI abatements through greenspace at both the strategic and practical level. The practical experience and guidance to emerge from the project will be of relevance to upscale the cooling benefit of single street trees to the city scale and beyond and will be of value across different sectors and internationally. Therefore, care will be taken to utilize a variety of dissemination

	opportunities including traditional communication channels such as event attendance (e.g. conferences, seminars, workshops, etc.), scientific publications (as well as conference papers, articles in journal of academic repute) and one field guide (describing the methods of getting field survey data and converting to the cooling effectiveness of urban trees) for the practitioners will be published. Attempts will also be made to link with a leading urban meteorologist such as Professor Sue Grimmond of University of Reading, UK to explore potential for upscaling the results from a single canopy to the city scale. Moreover, to disseminate the outcome of the project to tree care professionals, research report will be submitted to the International Society of Arboriculture's (ISA) magazines and newsletters. Final results and models with the practitioner's guide book will be submitted for presentation at 102nd Annual Ecological Society of America Meeting at Portland, Oregon, USA, 2017 and ISA Annual International Conference 2017 in Washington, D.C., USA.
Project start date	02/01/2016
Project completion date	01/31/2017
Geographic range of project	Europe & North Eurasia

Budget

Compensation/Stipend

Proposed project budget	36000
Requesting from TREE Fund	0
Funding from other sources	36000
Value of in-kind support from other sources	19000

Employee Benefits

Proposed project budget	0
Requesting from TREE Fund	0
Funding from other sources	0
Value of in-kind support from other sources	0

Travel (> 50 miles)

Proposed project budget	2000
Requesting from TREE Fund	0
Funding from other sources	2000

Value of in-kind support from other sources	1000

Local Transportation (< 50 miles)

Proposed project budget	400
Requesting from TREE Fund	0
Funding from other sources	400
Value of in-kind support from other sources	1500

Equipment (vehicles, growth chambers, etc.)

Proposed project budget	29000
Requesting from TREE Fund	10000
Funding from other sources	19000
Value of in-kind support from other sources	15000

Supplies (paper, ink, toner, etc.)

Proposed project budget	500
Requesting from TREE Fund	0
Funding from other sources	500
Value of in-kind support from other sources	300

Contract Labor (contractor, speaker, etc.)

Proposed project budget	0
Requesting from TREE Fund	0
Funding from other sources	0
Value of in-kind support from other sources	0

Other/Misc.

Proposed project budget	1500
Requesting from TREE Fund	0

Funding from other sources	1500
Value of in-kind support from other sources	500
Description of other/misc. expenses	Fuel and maintenance cost of Laser scanner and other equipment, hiring students during installation and uninstallation of equipment, publication of practitioner's guide book.

Total

Proposed project budget	69400
Requesting from TREE Fund	10000
Funding from other sources	59400
Value of in-kind support from other sources	37300

Funds already received from other sources	55500
Funds pending from other sources	3900
Value of in-kind support already received from other sources	34300
Value of in-kind support pending from other sources	3000

How did you hear about this grant?	TREE Fund website TREE Fund newsletter TREE Fund conference booth Word of mouth

Applications will be scored on the following scale:

- Applicant is qualified (0-10)
- Applicant has experience (0-10)
- Project directly meets one or all TREE Fund priorities (0-10)
- Project has clearly stated need (0-10)
- Project is clearly linked to arboriculture and/or urban forestry (0-10)
- Research has practical application (0-10)
- Methods are clear (0-10)
- Objectives are achievable within proposed time frame (0-10)
- Objectives are achievable within proposed budget (0-10)
- Requested funds are matched cash or in-kind (0-10)

Your application will not be available for editing after it has been submitted.
Please review your application for completion before submission.