User: justin.morgenroth@canterbury.ac.nz

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ADMIN: Reason(s) Not Eligible

John Z. Duling Grant Application

Please note: This application may only be submitted July 1 - October 1.

If you have any questions, please email bduke@treefund.org or call 630-369-8300 x200.

Applicant

Principal Investigator

Prefix	Dr.
First name	Justin
Last name	Morgenroth
Status	Professor
Title	Senior Lecturer
Organization	University of Canterbury
Mailing address	NZ School of Forestry, University of Canterbury
Mailing address line 2	Private Bag 4800
City	Christchurch
State/province	
Zip/post code	8140
Country	New Zealand
Email address	justin.morgenroth@canterbury.ac.nz

Phone number	+64210617123
Degrees	PhD - Forestry Science, 2011, University of Canterbury Masters of Forest Conservation, 2006, University of Toronto Bachelor of Science (Computer Science), 2002, University of Western Ontario
Relevant citations authored	A.K. Koeser, J. Roberts, J.W. Miesbauer, A. Bannwart Lopes, G.J. Kling, M. Lo, and J. Morgenroth. 2016. Testing the accuracy of imaging software for measuring tree root volumes. Urban Forestry and Urban Greening 18(1), 95 – 99. Scharenbroch, B.C., Morgenroth, J. & Maule, B. 2015. Tree Species Suitability to Bioswales and Impact on the Urban Water Budget. Journal of Environmental Quality, 45(1): 199 - 206. Morgenroth, J., Santos, B. & Cadwallader, B. 2015. Conflicts between landscape trees and lawn maintenance equipment – The first look at an urban epidemic. Urban Forestry & Urban Greening, 14(4):1054-1058. Miller, J., Morgenroth, J. & Gomez, C. 2015. 3D modelling of individual trees using a handheld camera: Accuracy of height, diameter and volume estimates. Urban Forestry & Urban Greening, 14(4), 932-940. Morgenroth, J., Visser, R., 2011. Above-Ground Growth Response of Platanus orientalis to Porous Pavements. Arboriculture and Urban Forestry 37(1), 1-5. Morgenroth, J. 2011. Root Growth Response of Platanus orientalis to Porous Pavements. Arboriculture and Urban Forestry, 37(1), 45-50. Morgenroth, J. 2008. A review of root barrier research. Arboriculture and Urban Forestry, 34, 84-88.
Has this investigator previously received funding from the TREE Fund?	Yes
If yes, was the funding for this project?	No
Previous TREE Fund awards	Image-based 3D Urban Tree Modelling. Thanks to this previous TREE Fund award, Dr. Morgenroth published two peer-reviewed scientific articles and presented at the 2014 ISA annual conference, as well as a local conference for the New Zealand Arboriculture Association. The TREE Fund was acknowledged for funding on all these occasions. Investigating Physical Soil Conditions and Tree Response to Permeable Paving. Thanks to this previous TREE Fund award, Dr. Morgenroth published 3 peer reviewed scientific articles and presented at 3 conferences (ISA 2009, 2011, and the Landscape Below Ground III) acknowledging the TREE Fund for their contribution.

Co-Principal Investigator (if applicable)

Prefix	Dr.
First name	Andrew
Last name	Koeser
Status	Professor
Title	Assistant Professor
Organization	University of Florida
Mailing address	Rm. 133, Gulf Coast Research and Education Centre
Mailing address line 2	14625 County Road 672
City	Wimauma
State/province	Florida
Zip/post code	33598
Country	United States
Email address	akoeser@ufl.edu
Phone number	0018136334150
Degrees	PhD – Crop Sciences (Horticulture/Biometry, 2013, University of Illinois at Urbana-Champaign MS – Natural Resources and Environmental Sciences, 2008, University of Illinois at Urbana-Champaign BS – Forestry (Urban Forestry), 2005, University of Wisconsin-Stevens Point
Relevant citations authored	A.K. Koeser, J. Roberts, J.W. Miesbauer, A. Bannwart Lopes, G.J. Kling, M. Lo, and J. Morgenroth. 2016. Testing the accuracy of imaging software for measuring tree root volumes. Urban Forestry and Urban Greening 18(1), 95 – 99. A Koeser, R Hauer, K Norris, R Krouse Factors influencing long-term street tree survival in Milwaukee, WI, USA. Urban forestry & urban greening 12 (4), 562-568 JR Stewart, RD Landes, AK Koeser, AL Pettay. Net photosynthesis and growth of three novel woody species under water stress: Calycanthus occidentalis, Fraxinus anomala, and Pinckneya pubens HortScience 42 (6), 1341-1345 A Koeser, JR Stewart. Effects of transplanting on the growth and survival of nursery stock. HORTSCIENCE 43 (4), 1239-1239
Has this investigator previously received funding from the TREE Fund?	Yes

If yes, was the funding for this project?	No
Previous TREE Fund awards	Miesbauer, J. and A.K. Koeser. 2015. “Assessing Wound-induced Response Growth in Two Common Urban Tree Species”. Hyland R. Johns Grant Program. This grant has been matched $5000 by the Florida Chapter of the International Society of Arboriculture (ISA). Work is beginning this month. Koeser, A.K., R. Hauer, and R. Northrop. 2013. Urban Tree Risk Assessment – Perceptions, Reality, and Reliability. Jack Kimmel International Grant Program. This grant was matched $5000 from Florida ISA and $5500 from the Wisconsin Arborist Association and used to leverage $50,000 in internal graduate student support from the University of Florida. To date, one paper from this work is published, three are submitted, and one is in progress. The work has been presented at over a dozen conferences and workshops. Most importantly, this serves as a thesis project for a very promising arboriculture professional. Koeser, A.K. and J.R. Stewart. 2010. Consequences and impacts of wire basket retention and removal on establishment and root morphology of a shallow-rooted and a deep-rooted tree species. Tree Research and Education Endowment Fund – John Z. Duling Grant. This grant was matched $5000 from the Wisconsin Arborist Association. To date the work resulted in a publication which was featured by ISA as one of its Arboriculture & Urban Forestry CEU offerings. A second paper on the impacts of wire basket retention/removal on rooting strength is in progress. The work has been featured in multiple presentations internationally and locally.

Students/Interns (if applicable)

Student/Intern 1

Name	Andrew Benson
Department or major	Forestry Science
Status	PhD student

Student/Intern 2

Name	
Department or major	
Status	

Student/Intern 3

Name

Department or major

Status

Project

Project title	Measuring tree response to increasing root removal intensities
Research area	Root and soil management Plant health care Urban forestry
Project summary	Conflicts often exist between trees in the urban forest and an ever increasing number of buildings, footpaths, new infrastructure and underground utilities. Such conflicts frequently result in the damage or complete removal of tree roots. While avoiding root damage is the most effective strategy for preserving tree health, site constraints can put trees in close proximity with development activities. Currently, arboricultural specialists rely on industry best practice documents informed by relatively few studies when deciding if a given tree can be retained or should be removed during site development. These documents feature largely anecdotal root diameter thresholds for identifying acceptable root removal limits. These thresholds fail to account for the size of the root(s) relative to the size of the tree, and also the total number of roots to be removed. Current best management practices (BMPs) also fail to account for the cumulative effects of repeated root injury resulting from site development and eventual redevelopment or repair. Funding is requested to help further understand the implications of root removal by examining precisely how trees respond to different root removal intensities. The study proposes to monitor physiological and tree growth responses to various root removal treatments in order to provide information to assist with the proper management of urban trees. The study has been designed to answer the questions; “How do trees respond to increasing root pruning intensity?” and “what proportion of a tree’s root system can be removed without significantly affecting growth and function?”
Statement of problem	Trees are under considerable stress from repeated injury during development activities (Koeser et al. 2013). The development and re-development of sites with trees has the potential to adversely affect root systems and overall tree health. These effects can be detrimental to tree health; often leading to an overall reduction in vitality, decline and in extreme cases, mortality. Throughout much of New Zealand, an arbitrary diameter threshold of 35 mm seems to have been established through industry consensus, above which the severance of roots is usually prohibited. The British Standard BS 5837:2005 – Trees in relation to construction (BSI, 2005) and National Joint Utilities Group (NJUG) guidelines (2007) suggest that this threshold should be 25mm. Neither of these methods accounts for the age or size of the tree, nor the total

numbers of roots being removed. In the instance of a juvenile tree, a 35 mm root may very well be contributing toward a noticeable proportion of the tree's water and nutrient uptake. Conversely, a 35 mm root would unlikely be contributing towards a comparable proportion of a mature tree's uptake of the same resources, and thus its removal may be inconsequential.

In contrast, the International Society of Arboriculture Best Management Practice guide for Managing Trees During Construction (Fite and Smiley 2008) does not specify a maximum diameter threshold for root removal. Rather, its guidelines are established with respect to distance from the tree's trunk. For broad spreading trees, a tree protection zone is ideally established at the dripline. For narrow-crowned species, the tree protection zone is established based on trunk diameter. A 6:1 ratio (i.e. 6 cm/inch of buffer for each cm/inch of trunk diameter) is considered the minimum and should be applied only to young and construction-tolerant trees. A more ideal 18:1 ratio is recommended for mature and construction-intolerant trees. As with the approach adopted in NZ and the UK, the ISA BMP approach does not account for the total number of roots being removed, nor their size.

Why do we accept these approaches to adopt arbitrary root diameter thresholds or trunk diameter based root protection zones, when a far greater understanding of a tree's response to root severance is required to make critical management decisions?

British Standards Institute. (2005). BS5837:2005 Trees in relation to construction – Recommendations
Fite, K, Smiley, E.T. (2008). Best Management Practices – Managing Trees During Construction. International Society of Arboriculture, Champaign, IL. pp. 35.

Koeser A, Hauer R, Norris K, Krouse R (2013) Factors influencing long-term street tree survival in Milwaukee, WI, USA Urban Forestry & Urban Greening 12:562-568
NJUG (2007). NJUG guidelines for the planning, installation and maintenance of utility apparatus in proximity to trees NJUG Publication: Volume 4: Issue 2: 16/11/2007

Significance of your proposed project as it relates to the profession of arboriculture or urban forestry

Urban trees are potentially long-lived organisms that will likely be exposed to construction damage one or more times over the course of their lives. Unfortunately, mature trees (which provide greater environmental, economic, and social services) are generally considered less resilient to the stresses of construction. There is a need to correctly manage physical works around established trees. In these instances, arboricultural experts may be required to make 'educated guesses' about the future health of affected trees based on their understanding of how the roots of trees are managed. This can lead to cases of un-justified tree removal or ill-advised tree retention, resulting in loss of benefits or increased potential for harm, respectively.

The results of the study will assist arboricultural experts and

practitioners alike by:

1. Providing information on how trees respond to varying levels of root pruning.

2. Enabling arborists to make more defensible decisions about root pruning; particularly where planning documents, hearings or environment court decisions are involved.

3. Providing evidence which can be used in the revision and preparation of best practice documents in the years to come.

Moreover, the profession will benefit from increased international collaboration because the researchers are from three different countries (New Zealand, United States, and United Kingdom). Finally, by building research capability in a PhD student whose background is firmly in arboricultural practice, the profession will benefit by establishing a link between research and practical arboriculture.

Description of what is currently known about proposed project area

Much of the current research in relation to root removal relates to anchorage and stability and has used pull tests to determine strength loss after root removal (Hamilton, 1988; Smiley, 2008; Ghani et al. 2009; Smiley, 2014). Often the methods attempt to replicate construction activities, where trenching is used to indiscriminately sever roots at a known distance from the tree base, occasionally as a ratio of DBH (i.e. two or three times the DBH). Smiley (2008) established a relationship between trunk diameter and linear trenching and found that, in order to avoid significant changes in the force required to rotate the trunk about the root ball, trenches should be dug no closer than three times DBH to the tree trunk. Later, Smiley (2014) established a reliable correlation ($r^2 = 0.82$) between pull force and root removal using the measured cross sectional area (CSA) of roots removed, as a proportion of DBH.

Despite a focus on tree stability, there have been some studies that have measured tree growth or vitality in response to root removal. Watson (1998) examined how root removal affected tree growth and vitality, again adopting linear trenching methods to sever roots using a DBH ratio of 12:1 (i.e. trenches were made 12 cm from the tree base for each 1 cm of DBH). He exposed trees to different trenching treatments, being on one, two or three sides of the tree and found that more severe trenching resulted in greater dieback and reduced tree growth (shoot and DBH growth).

Recently, Fini et al. (2014), evaluated the long term effects of different levels of root severance on growth and physiology of two tree species. Fini recorded the same observation as Watson (1998) in relation to tree growth in response to different root removal treatments, but also examined the physiological effects of root severance. Changes in stomatal conductance were observed in root-pruned trees over the four-year period immediately following the root removal treatments, when compared to controls. As with other studies, the roots were removed indiscriminately by trenching at a

fixed distance from the tree base (i.e. not proportional to the DBH) and crucially, the extent of the root removal itself was not quantified. The study concluded that root damage indirectly induces a chronic but mild water stress to root-severed trees, even when soil water availability was not limiting.

These previous studies show that: a) DBH can be used to estimate an 'acceptable' trenching distance that limits negative impacts on stability, growth, and vitality; b) physiological measurements can be used to explain 'why' root removal negatively affects the vitality and growth of trees. But an important question remains unanswered. In all previous studies, roots were indiscriminately severed via trenching, and neither the size of severed roots, nor the proportion of total root cross sectional area affected by trenching were measured. Unfortunately, this leaves a sizeable gap in our understanding of the impacts of root removal on tree stability, growth and condition. For example, the previous research cannot be used to answer whether removing a single 35 mm diameter root from a 15 cm DBH tree will affect stability, growth, or vitality.

We propose to address this knowledge gap and to provide practical benefits to arboricultural experts and tree managers alike. The study will build on the previous research, by quantifying root removal relative to tree size and measuring responses in growth, physiology, and condition.

Fini, A. Frangi, P. Amoroso, G. Piatti, R. Robbiani, E. Sani, L. Bonanomi, L. Blotta, V and Ferrini, F. (2014). Effects of root severance by excavation on growth, physiology and stability of two urban tree species: results from a long-term experiment. International Society of Arboriculture Annual Conference, Milwaukee, WI.

Ghani, M, A. Stokes, A and Fourcaud, T. (2009) The effect of root architecture and root loss through trenching on the anchorage of tropical urban trees (Eugenia grandis Wight). Trees 23:197–209

Hamilton, W.D. (1988). Significance of root severance on performance of established trees. Journal of Arboriculture 14(12): 288-292.

Smiley, E, T. (2008) Root Pruning and Stability of Young Willow Oak. Arboriculture & Urban Forestry 34(2):123–128.

Smiley, E, T. Holmes, L, and Fraedrich, B (2014) Pruning of Buttress Roots and Stability Changes of Red Maple (Acer rubrum) Arboriculture & Urban Forestry 40(4): 230–236

Watson, G (1998) Tree growth after trenching and compensatory pruning. Journal of Arboriculture 24(1): 47-53.

Summary of project goals

1.Challenge current thinking on the management of tree root zones.

2.Describe how trees respond to increasing root pruning intensity. This will enable practitioners to determine more acceptable,

	defensible root removal thresholds designed to minimize impact on tree growth and function 3.Disseminate the research at an ISA conference and in relevant scientific and practitioner publications worldwide. We anticipate the information to be relevant to a wide audience and that the dissemination of findings will persist for some years after the study is complete. 4.Work with ISA and local chapters to incorporate the results into best practice documents in the years following the study. 5.Contribute to improving the research capability of a PhD student in arboriculture and urban forestry related studies. 6.Build bridges in international arboriculture and urban forestry research using a project team from three countries.
Description of measurable outcomes expected	We aim to produce measureable outputs that communicate the results of the research to both scientific and practitioner audiences. All written and oral outputs will identify TREE Fund as a sponsor. Our primary goal is to produce outputs that provide value to the fields of arboriculture and urban forestry with clear practical benefits. However, a secondary goal is to produce an outward facing scientific publication to highlight that cutting edge research is being conducted in our urban forests. Our measurable outputs will be: 1.A manuscript for a scientific audience (publication in one of Arboriculture & Urban Forestry or Urban Forestry & Urban Greening) 2. A technology transfer article for a practitioner audience (publication in Arborist News, City Trees, or similar industry magazine). 3.Present results at annual ISA international and local chapter conferences. 4.Manuscript for scientific audience not generally associated with arboriculture or urban forestry. This is likely to be published in a journal associated with plant physiology. 5.Developing the capabilities of a young researcher who will serve the field for decades to come.
Project plan including design, hypotheses, methodology and analyses	Research Questions: The study has been designed to use established and proven methods to answer the questions; “How do trees respond to increasing root pruning intensity?” and “what proportion of a tree’s root system can be removed without significantly affecting growth and function?” This research will be completed by a PhD student under the supervision of the co-applicants. We have worked closely with various tree suppliers, local authorities and arboricultural contractors in New Zealand and the USA to establish trial sites and secure tree stock to undertake the field work.

Study Site:
The research will be conducted at the Christchurch City Council (CCC) nursery in Christchurch, New Zealand and at the Gulf Coast Research and Education Center in Florida, USA. Having field sites in two geographically distant locations is desirable to better understand how trees respond to root severance in both a dry temperate climate (Christchurch) and a humid sub-tropical climate (Florida), and will yield a greater applicability of the results for practitioners around the world.

Trees:
We will use landscape-grade, open grown trees for our experiment. We are currently negotiating which trees at the CCC nursery we can use for the research. We will select a deciduous broadleaf species that is commonly planted in cities globally. We will include 50 trees in the Christchurch-based experiment. We have already secured 50 bald cypresses (Taxodium distichum) for the Florida-based experiment.

Experimental Design:
Trees in the experiment will either be assigned to a control group (no root severance) or a treatment group (varying intensity of root severance). Root severance will be undertaken on each of the treatment groups to encompass a wide range of root removal intensities for which the tree responses can be measured. Trenches will be excavated with an air spade on one, two, three or all four sides of each tree in the treatment groups, and roots in each trench will be severed. Importantly, the total root cross-sectional area (RCSA) for severed roots will be measured to quantify the severity and impact of trenching. This approach will achieve a range of measurable root removal intensities. The proportion of total RCSA to trunk cross-sectional area (TCSA) will be calculated and expressed as a percentage. This metric ((RCSA/TCSA) * 100) will act as a continuous variable used to explain measured changes in tree growth, condition and physiology. Specifically, the response variables that we will measure include trunk diameter at breast height and shoot extension (tree growth), crown dieback (tree condition), as well as chlorophyll fluorescence and stomatal conductance (tree physiology).

Detailed Methods:
There are four critical steps to answer the research questions. We need to 1) Undertake trenching; 2) Remove roots to establish a full range of root removal intensities; 3) Determine TCSA for all trees and RCSA for all roots; and 4) monitor tree response to root severance. These steps are expanded upon below.

1. Undertake trenching
- Use an air spade to excavate trenches on one, two, three or four sides of each tree. Trees assigned to the control group will have no trenches excavated.
2. Remove roots

- Sever all roots in each trench with a hand saw or secateurs.
- Remove severed roots from soil for measurement in next step
- Fill trenches with original soil material and lightly compact.

3. Determine TCSA and RCSA
- Measure trunk diameter (DBH) at 1.4 m above ground level.
- Estimate trunk cross sectional area (TCSA) from DBH.
- Measure the diameter of the cut end of roots removed from each trench.
- Estimate total root cross-sectional area (RCSA).
- Calculate the ratio of RCSA to TCSA as a percentage, ((RCSA/TCSA) * 100).

4. Monitor tree response to root severance
- Measure DBH monthly during the growing season
- Measure shoot extension monthly during the growing season
- DBH and shoot extension will be measured using the same methods as Watson's 1998 study to ensure our results can be compared to previous work.
- Measure crown dieback monthly during the growing season
- Measure chlorophyll fluorescence (CF) weekly during the growing season. CF is an accepted way to understand the efficiency of photosynthesis and is therefore a useful way to measure stress.
- Measure stomatal conductance (SC) weekly for all trees. SC is a measure of gas exchange and transpiration in trees, and changes in SC are a useful indicator of stress.
- Air temperature and relative humidity will be measured for all days on which CF and SC are measured as these climatic variables can significantly affect tree physiology.

Statistical analysis:
The results will be analyzed to examine the relationship between the root cross-sectional area removed and tree growth, condition, and stress responses. Statistical regression analyses will be undertaken to explain the relationship between the explanatory variable (ratio of RCSA to TCSA, expressed as a percentage) and response variables (tree growth (DBH, shoot extension), condition (crown dieback), and physiology (CF, SC)). The null hypothesis that we will test is: There is no significant effect of increasing root removal intensity on measurable growth, condition, and stress responses. Testing this hypothesis will allow us to confidently answer the stated research questions.

Smiley, E, T. Holmes, L, and Fraedrich, B (2014) Pruning of Buttress Roots and Stability Changes
of Red Maple (Acer rubrum) Arboriculture & Urban Forestry 40(4): 230–236

Watson, G (1998) Tree growth after trenching and compensatory pruning. Journal of Arboriculture 24(1): 47-53.

Description of plan for disseminating the results of this

We aim to communicate the results of the research to both scientific and practitioner audiences using various methods of dissemination.

project	All written and oral outputs will identify TREE Fund as a sponsor. Our primary goal is to produce outputs that provide value and practical benefits to the fields of arboriculture and urban forestry. The secondary goal is to produce an outward facing scientific publication to highlight that cutting edge research is being conducted in our urban forests. Our measurable outputs will be: 1.A manuscript for a scientific audience (publication in one of A&UF or UFUG) 2.A technology transfer article for a practitioner audience (publication in Arborist News, City Trees, or similar industry magazine). 3.Present results at annual ISA international and local chapter conferences. 4.Manuscript for scientific audience not generally associated with arboriculture or urban forestry. This is likely to be published in a journal associated with plant physiology. 5.Developing the capabilities of a young researcher who will serve the field for decades to come.
Project start date	10/01/2016
Project completion date	09/30/2019
Geographic range of project	USA & Canada Latin America Europe & North Eurasia Asia & Pacific Middle East Africa

Budget

Compensation/Stipend

Proposed project budget	$88,242.98
Requesting from TREE Fund	$0
Funding from other sources	$74,405.48
Value of in-kind support from other sources	$13,837.50

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	$7,916.25
Requesting from TREE Fund	$7,916.25
Funding from other sources	$0
Value of in-kind support from other sources	$0

Local Transportation (< 50 miles)

Proposed project budget	$450.00
Requesting from TREE Fund	$450.00
Funding from other sources	$0
Value of in-kind support from other sources	$0

Equipment (vehicles, growth chambers, etc.)

Proposed project budget	$5,625.00
Requesting from TREE Fund	$5,625.00
Funding from other sources	$0
Value of in-kind support from other sources	$0

Supplies (paper, ink, toner, etc.)

Proposed project budget	$2,175.00
Requesting from TREE Fund	$2,175.00
Funding from other sources	$0
Value of in-kind support from other sources	$0

Contract Labor (contractor, speaker, etc.)

Proposed project budget	$5,000.00
Requesting from TREE Fund	$5,000.00
Funding from other sources	$0

Value of in-kind support from other sources	$0

Other/Misc.

Proposed project budget	$8,810.00
Requesting from TREE Fund	$3,810.00
Funding from other sources	$5,000.00
Value of in-kind support from other sources	$0
Description of other/misc. expenses	accommodation and per-diem for PhD student and technician while working at field sites away from home base. Also includes hotel accommodation costs for presenting results of this research at a future ISA conference. Also includes costs of purchasing trees for use in research.

Total

Proposed project budget	118219.23
Requesting from TREE Fund	24976.25
Funding from other sources	79405.48
Value of in-kind support from other sources	13837.5
Funds already received from other sources	79405.48
Funds pending from other sources	$15,000
Value of in-kind support already received from other sources	13837.50
Value of in-kind support pending from other sources	$0
How did you hear about this grant?	Other

Applications will be scored on the following scale:

- Applicant is qualified (10 points)
- Applicant has experience (5 points)
- Project has potential to result in transformative research ideas or approaches (5 points)
- Project directly meets one or all TREE Fund priorities (10 points)
- Project has clearly stated need (10 points)
- Project is clearly linked to arboriculture and/or urban forestry (5 points)
- Research has practical application (10 points)
- Project design is scientifically sound, methods are clear and analysis is appropriate (15 points)
- Project is likely to result in peer reviewed publication (10 points)
- Objectives are achievable within proposed time frame (5 points)
- Objectives are achievable within proposed budget (5 points)
- Requested funds have potential to leverage future support from other funding sources (5 points)
- Requested funds are matched with at least 10% cash or in-kind (5 points)

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