Cover Page for Proposal Submitted to the National Aeronautics and Space Administration

NASA Proposal Number

15-LCLUC15_2-0050

NASA PROCEDURE FOR HANDLING PROPOSALS

This proposal shall be used and disclosed for evaluation purposes only, and a copy of this Government notice shall be applied to any reproduction or abstract thereof. Any authorized restrictive notices that the submitter places on this proposal shall also be strictly complied with. Disclosure of this proposal for any reason outside the Government evaluation purposes shall be made only to the extent authorized by the Government.

SECTION I - Proposal Information

Principal Investigator	E-mail Address	Phone Number
Forrest Fleischman	**forrestf@tamu.edu**	**734-834-6246**

Street Address (1)	Street Address (2)
2138 Tamu	

City	State / Province	Postal Code	Country Code
College Station	**TX**	**77843-0001**	**US**

Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**

Proposed Start Date	Proposed End Date	Total Budget	Year 1 Budget	Year 2 Budget	Year 3 Budget
01 / 01 / 2017	**12 / 31 / 2019**	**749,999.00**	**268,309.00**	**277,530.00**	**204,160.00**

SECTION II - Application Information

NASA Program Announcement Number	NASA Program Announcement Title
NNH15ZDA001N-LCLUC	**Land Cover / Land Use Change**

For Consideration By NASA Organization *(the soliciting organization, or the organization to which an unsolicited proposal is submitted)*

Earth Science

Date Submitted	Submission Method	Grants.gov Application Identifier	Applicant Proposal Identifier
06 / 01 / 2016	**Electronic Submission Only**		

Type of Application	Predecessor Award Number	Other Federal Agencies to Which Proposal Has Been Submitted
New		

International Participation	Type of International Participation
Yes	**Collaborator**

SECTION III - Submitting Organization Information

DUNS Number	CAGE Code	Employer Identification Number (EIN or TIN)	Organization Type
847205713	**00JP8**		**2A**

Organization Name (Standard/Legal Name)	Company Division
Texas A&M AgriLife Research	
Organization DBA Name	Division Number

Street Address (1)	Street Address (2)
2147 TAMU	

City	State / Province	Postal Code	Country Code
COLLEGE STATION	**TX**	**77843**	**USA**

SECTION IV - Proposal Point of Contact Information

Name	Email Address	Phone Number
Forrest Fleischman	**forrestf@tamu.edu**	**734-834-6246**

SECTION V - Certification and Authorization

Certification of Compliance with Applicable Executive Orders and U.S. Code

By submitting the proposal identified in the Cover Sheet/Proposal Summary in response to this Research Announcement, the Authorizing Official of the proposing organization (or the individual proposer if there is no proposing organization) as identified below:

- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in this solicitation.

Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

Authorized Organizational Representative (AOR) Name	AOR E-mail Address	Phone Number
Anna Jahn	**ajahn@tamu.edu**	**979-458-4983**

AOR Signature *(Must have AOR's original signature. Do not sign "for" AOR.)* Date

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050

Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**

SECTION VI - Team Members

Team Member Role	Team Member Name	Contact Phone	E-mail Address
PI	**Forrest Fleischman**	**734-834-6246**	**forrestf@tamu.edu**
Organization/Business Relationship: **Texas A&M AgriLife Research**		Cage Code: **00JP8**	DUNS#: **847205713**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I	**Ashwini Chhatre**	**217-244-3485**	**achhatre@illinois.edu**
Organization/Business Relationship: **INDIAN SCHOOL OF BUSINESS**		Cage Code: **SRP27**	DUNS#: **675829417**
International Participation: **Yes**	U.S. Government Agency		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I	**Anthony Filippi**	**979-845-5744**	**filippi@tamu.edu**
Organization/Business Relationship: **Texas A & M, College Station**		Cage Code: **1T3H7**	DUNS#: **020271826**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I	**Harry Fischer**	**91-990-811-7284**	**hfischer84@gmail.com**
Organization/Business Relationship: **INDIAN SCHOOL OF BUSINESS**		Cage Code: **SRP27**	DUNS#: **675829417**
International Participation: **Yes**	U.S. Government Agency		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I	**Urs Kreuter**	**979-255-2022**	**urs@tamu.edu**
Organization/Business Relationship: **Texas A&M University**		Cage Code: **N/A**	DUNS#: **N/A**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I	**Pushpendra Rana**	**91-86280-68190**	**pranaifs27@gmail.com**
Organization/Business Relationship: **Self**		Cage Code: **N/A**	DUNS#: **N/A**
International Participation: **Yes**	U.S. Government Agency		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I	**Claudia Rodriguez Solorzano**	**734-846-4869**	**claudiarsolorzano@gmail.com**
Organization/Business Relationship: **Texas A&M AgriLife Research**		Cage Code: **00JP8**	DUNS#: **847205713**
International Participation: **No**	U.S. Government Agency		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I/Institutional PI	**Eric Coleman**	**801-391-8263**	**ecoleman@fsu.edu**
Organization/Business Relationship		Cage Code	DUNS#
Florida State University		**3S772**	**790877419**
International Participation	U.S. Government Agency		Total Funds Requested
No			**0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I/Institutional PI	**Burak Guneralp**	**979-595-7262**	**bguneralp@tamu.edu**
Organization/Business Relationship		Cage Code	DUNS#
Texas A & M, College Station		**1T3H7**	**020271826**
International Participation	U.S. Government Agency		Total Funds Requested
No			**0.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050

Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**

SECTION VII - Project Summary

Artificial afforestation programs are emerging as important policy interventions globally to increase carbon sequestration, yet there has been little systematic study of the impacts of afforestation programs on the livelihoods of forest dependent people. Afforestation projects do not simply improve ecosystem service provision, as widely assumed; they replace other land-cover types – such as grasslands, savannas, or degraded forests – thus changing the mix of goods provided by these ecosystems. Depending on the species planted and the success of the plantation, afforestation may increase the availability of timber and fuelwood while decreasing availability of fodder and some non-timber forest products. Livelihood impacts will depend on the importance of these goods and services to different households, the availability of alternatives, and the capacity of households to respond. As a result, plantations may improve the livelihoods of some households while hurting others, particularly those dependent on non-forest resources produced on lands converted to plantation. Better understanding of the effects of plantations on livelihoods is crucial for designing policies that maximize the positive benefits and mitigate negative impacts of afforestation.

We propose to study the impact of afforestation programs in India, a country in which afforestation efforts are extensive, on the livelihoods of the rural poor. We will do so by combining recent government data on afforestation with long-term estimates of afforestation based on NASA satellite data and household surveys in 140 villages with varying levels of exposure to afforestation. In April of 2016, we obtained government records for all 2252 plantations made by the state forest department in the Kangra district of the Western Himalayan state of Himachal Pradesh between 2005-2015. We will combine this data with ground-truthing in a subset of these plantations. We will conduct land-cover/land-use change (LCLUC) analysis based upon use of an advanced image endmember-estimation algorithm and spectral unmixing/endmember mapping. This will allow us to detect and differentiate different types of small plantations using historical Landsat data. We will conduct household livelihood surveys in a sample of 140 villages which have been exposed to different types of plantations. Combining estimates of afforestation activities with household livelihood data will allow us to estimate, using regression and propensity score matching techniques, the impacts of afforestation on the livelihoods of households with different characteristics. These analyses will allow us to develop guidelines, which will help Indian policy-makers develop and implement plantation programs that align the imperative for carbon sequestration with the needs and interests of the poor.

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050

Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**

SECTION VIII - Other Project Information

Proprietary Information

Is proprietary/privileged information included in this application?

Yes

International Collaboration

Does this project involve activities outside the U.S. or partnership with International Collaborators?

Yes

Principal Investigator	Co-Investigator	Collaborator	Equipment	Facilities
No	**No**	**Yes**	**No**	**No**

Explanation :

We will collaborate with the Revitalizing Rainfed Agriculture Network Research Node at the Indian School of Business in Hyderabad, India, to select field sites in which they have existing data collection efforts, and thus leverage joint data collection efforts. Our Indian collaborators have their own funding, and will not need funding to collaborate with us.

NASA Civil Servant Project Personnel

Are NASA civil servant personnel participating as team members on this project (include funded and unfunded)?

No

Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year
Number of FTEs	Number of FTEs	Number of FTEs	Number of FTEs	Number of FTEs	Number of FTEs

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050

Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**

SECTION VIII - Other Project Information

Environmental Impact

Does this project have an actual or potential impact on the environment?	Has an exemption been authorized or an environmental assessment (EA) or an environmental impact statement (EIS) been performed?
No	**No**

Environmental Impact Explanation:

Exemption/EA/EIS Explanation:

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Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**

SECTION VIII - Other Project Information

Historical Site/Object Impact

Does this project have the potential to affect historic, archeological, or traditional cultural sites (such as Native American burial or ceremonial grounds) or historic objects (such as an historic aircraft or spacecraft)?

No

Explanation:

SECTION IX - Program Specific Data

Question 1 : Short Title:

Answer: Impacts of artificial afforestation on sustainable livelihoods in rural communities in India: A Step-2 proposal in response to NASA solicitation NNH15ZDA001N-LCLUC Impacts of artificial afforestation on the provision of ecosystem services to rural communities in India: A Step-2 proposal in response to NASA solicitation NNH15ZDA001N-LCLUC

Question 2 : Type of institution:

Answer: Educational Organization

Question 3 : Will any funding be provided to a federal government organization including NASA Centers, JPL, other Federal agencies, government laboratories, or Federally Funded Research and Development Centers (FFRDCs)?

Answer: No

Question 4 : Is this Federal government organization a different organization from the proposing (PI) organization?

Answer: No

Question 5 : Does this proposal include the use of NASA-provided high end computing?

Answer: No

Question 6 : Research Category:

Answer: 9) Earth System Science applications and decision support

Question 7 : Data Management Plan (Part 1)

Answer:

This Data Management Plan is proposed for the project "Impacts of artificial afforestation on the provision of ecosystem services to rural communities in India," A Step-2 proposal in response to NASA solicitation NNH15ZDA001N-LCLUC. The PI for this project is Forrest Fleischman, and he will be responsible for implementing and amending this data management plan. He will be assisted in implementing this plan by Co-Investigators Burak Guneralp (spatial data) and Eric Coleman (survey data).The aim of this research is to evaluate the impact of afforestation on livelihoods in India. This research project will generate three primary kinds of data:A. Analyses of government plantation records stored as .csv data files (readable by Excel, etc)B. Household survey data, stored as .csv data files (readable by Excel, etc)C. Spatial data, including geographic information system (GIS) data files, remote-sensing data/images, and georeferenced field data.Although linked conceptually, the distinct nature of these three data types means each will be treated differently, and are described separately below.A. Analyses of government plantation recordsUnder India's Right to Information Act, government records are publicly available on request. We have obtained government records of plantations in Kangra District of India between 2005-2015, and will be creating a database of these plantations, including information about plantation area, species planted, maintenance activities performed, and money spent. This database will be stored in a .csv format.B. Household Survey dataHousehold survey data will be collected using tablets and offline data collection applications (most likely Qualtrics Offline or Kobotoolbox), which will be uploaded regularly when field enumerators have internet access. Data from these systems will be regularly downloaded by the PI and stored as Excel-readable .csv files. These survey systems will allow us to georeference the location of every survey. While this georeferenced data is essential for calculations

of the proximity of households to mapped plantation areas, it could also allow for breaches of confidentiality with households, and for this reason, the georeferences for respondents will be stored in a separate password protected database which only the Co-Investigators and postdoc working on this project will have access to, and will not be shared under the data sharing process described below. Products produced from georeferenced data which will not allow identification of individuals, such as distances of households to plantation areas, will be shared.C. Spatial dataThe proposed project will generate significant amounts of geospatial data and supporting documentation, including geographic information system (GIS) data files, remote-sensing data/images, and georeferenced field data. In order to allow for ease of use by all team members, all GIS datasets and corresponding metadata will be stored in proprietary GIS formats (i.e., ESRI files/ ArcGIS data layers), ASCII text files, and in a format that complies with Open Geospatial Consortium, Inc.® (OGC®) Standards and Specifications (http://www.opengeospatial.org/). Field data (e.g., GPS data, field notes, etc.) will be collected in digital form, and will be stored according to the same standards as other GIS data. Remote-sensing images will be received by the PIs in a variety of sensor-specific formats. When possible, the format will be standardized to generic binary data files. GIS data will be stored as ESRI files/ArcGIS data layers, ASCII text files, and OGC®-compliant files. Remote-sensing data/images will be stored as generic binary data files, as possible.

Question 8 : Data Management Plan (Part 2)

Answer:

Data Storage:All data will be housed in data-storage facilities at Texas A&M University (TAMU)- College Station. These data-storage facilities/data servers are located within the TAMU College of Geosciences, in the basement of the Oceanography and Meteorology (O&M) Building. Consistent data backups are provided by the College of Geosciences, and for the purpose of data security and integrity, only the PIs and other project members will have access to the original data stored on these servers.Data sharing/access practices and policies; policies and provisions for re-use, re-distribution:Scientific data directly associated with this project will be available to the public after appropriate quality validation of the materials has been conducted and initial scientific peer-reviewed publications have been submitted. As mentioned above, georeferenced locations of surveyed households will not be made available to anyone outside of the project team. The procedure for requesting the data will include formally contacting the PI(s) and requesting the data. The requesting party must include in their request what the intended use of the data will be. The data are intended for non-commercial use only. Any scientific studies/publications that result from the use of these data must properly acknowledge the original source of the data, and include references to the original publications associated with the scientific data. The transfer of data will be via the internet depending on the storage location of the requested data. If an alternative form of data transfer is needed (e.g., data cartridges, CDs/DVDs), the requesting party is responsible for all costs involved including purchasing of the blank multi-media disks/cartridges, labor to transfer data to multi-media disks/cartridges for shipment, and shipping including packaging and insurance. Regarding the educational modeling tool and associated laboratory module, data access will be provided via the web, as noted above.Remote-sensing image/data-derived products and GIS data layers (e.g., plantation boundaries in GIS format, etc.) produced by the PIs or postdoctoral/graduate researchers will be made available for data sharing, unless there is any data user license agreement, or protection of privacy, confidentiality, security, intellectual property, or other rights requirement that would prohibit sharing of such data.Archiving of data.Critical data will periodically be backed-up on physical, archival-qualityCD/DVD/Blu-ray discs, as well as stored in data-storage facilities at Texas A&M University (see above for details). Project data will also be backed-up at the conclusion of the project. Since archival-quality discs, which have a preservation lifespan of over 200 years, will be used for permanent backup, this will minimize the need to frequently transfer data to replacement discs/ media at the end of product life. However, as new storage media, devices, technological standards, or practices are developed or change, we will assess the need to transfer the digital information in accordance with new developments, and we will act in a manner that will ensure that continued safe storage of and access to the project data. All archived project data, regardless of storage media and location (e.g., on servers, fireproof/waterproof hard drives, archival-quality discs, etc.), will be accompanied by an index-in a standard, non-proprietary format (e.g., ASCII text file)-that documents all archived data-storage locations and how they can be accessed. Data quality assessments and other relevant supporting ancillary information will be included.

Question 9 : Team Members Missing From Cover Page:

Answer:

none

Question 10 : Does this proposal contain information and/or data that are subject to U.S. export control laws and regulations including Export Administration Regulations (EAR) and International Traffic in Arms Regulations (ITAR)?

Answer: Yes

Question 11 : I have identified the export-controlled material in this proposal.

Answer: No

Question 12 : I acknowledge that the inclusion of such material in this proposal may complicate the government's ability to evaluate the proposal.

Answer: Yes

Question 13 : Does the proposed work include any involvement with collaborators in China or with Chinese organizations, or does the proposed work include activities in China?

Answer: No

Question 14 : Are you planning for undergraduate students to be involved in the conduct of the proposed investigation?

Answer: No

Question 15 : If yes, how many different undergraduate students?

Answer: N/A

Question 16 : What is the total number of student-months of involvement for all undergraduate students over the life of the proposed investigation?

Answer: none

Question 17 : Provide the names and current year (1,2,3,4) for any undergraduate students that have already been identified.

Answer:

n/a

Question 18 : Are you planning for graduate students to be involved in the conduct of the proposed investigation?

Answer: Yes

Question 19 : If yes, how many different graduate students?

Answer: 1

Question 20 : What is the total number of student-months of involvement for all graduate students over the life of the proposed investigation?

Answer: 10

Question 21 : Provide the names and current year (1,2,3,4, etc.) for any graduate students that have already been identified.

Answer:

To be named

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050
Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**	

SECTION X - Budget

Cumulative Budget

Budget Cost Category	Funds Requested ($)			
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total Project ($)
A. Direct Labor - Key Personnel	**20,947.00**	**21,527.00**	**22,127.00**	**64,601.00**
B. Direct Labor - Other Personnel	**57,593.00**	**59,071.00**	**60,593.00**	**177,257.00**
Total Number Other Personnel	**1**	**1**	**1**	**3**
Total Direct Labor Costs (A+B)	**78,540.00**	**80,598.00**	**82,720.00**	**241,858.00**
C. Direct Costs - Equipment	**0.00**	**0.00**	**0.00**	**0.00**
D. Direct Costs - Travel	**14,300.00**	**12,000.00**	**4,750.00**	**31,050.00**
Domestic Travel	**1,000.00**	**1,000.00**	**1,000.00**	**3,000.00**
Foreign Travel	**13,300.00**	**11,000.00**	**3,750.00**	**28,050.00**
E. Direct Costs - Participant/Trainee Support Costs	**0.00**	**0.00**	**0.00**	**0.00**
Tuition/Fees/Health Insurance	**0.00**	**0.00**	**0.00**	**0.00**
Stipends	**0.00**	**0.00**	**0.00**	**0.00**
Travel	**0.00**	**0.00**	**0.00**	**0.00**
Subsistence	**0.00**	**0.00**	**0.00**	**0.00**
Other	**0.00**	**0.00**	**0.00**	**0.00**
Number of Participants/Trainees				**0**
F. Other Direct Costs	**103,185.00**	**115,772.00**	**74,267.00**	**293,224.00**
Materials and Supplies	**1,200.00**	**0.00**	**0.00**	**1,200.00**
Publication Costs	**0.00**	**0.00**	**0.00**	**0.00**
Consultant Services	**0.00**	**0.00**	**0.00**	**0.00**
ADP/Computer Services	**0.00**	**0.00**	**0.00**	**0.00**
Subawards/Consortium/Contractual Costs	**71,985.00**	**65,772.00**	**74,267.00**	**212,024.00**
Equipment or Facility Rental/User Fees	**0.00**	**0.00**	**0.00**	**0.00**
Alterations and Renovations	**0.00**	**0.00**	**0.00**	**0.00**
Other	**30,000.00**	**50,000.00**	**0.00**	**80,000.00**
G. Total Direct Costs (A+B+C+D+E+F)	**196,025.00**	**208,370.00**	**161,737.00**	**566,132.00**
H. Indirect Costs	**72,284.00**	**69,160.00**	**42,423.00**	**183,867.00**
I. Total Direct and Indirect Costs (G+H)	**268,309.00**	**277,530.00**	**204,160.00**	**749,999.00**
J. Fee	**0.00**	**0.00**	**0.00**	**0.00**
K. Total Cost (I+J)	**268,309.00**	**277,530.00**	**204,160.00**	**749,999.00**
Total Cumulative Budget				**749,999.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
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Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2017	**12 / 31 / 2017**	**Project**	**1**

A. Direct Labor - Key Personnel

Name	Project Role	**Base Salary ($)**	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	**Fringe Benefits ($)**	Funds Requested ($)
Fleischman, Forrest	**PI_TYPE**	**7,930.00**	**1**			**8,165.00**	**2,148.00**	**10,313.00**
Kreuter, Urs	**CO-I**	**10,552.00**	**.25**			**2,713.00**	**656.00**	**3,369.00**
Rodriguez Solorzano, Claudia	**CO-I**	**5,416.00**	**1**			**5,577.00**	**1,688.00**	**7,265.00**
							Total Key Personnel Costs	**20,947.00**

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	**Post Doctoral Associates**	**12**			**41,811.00**	**15,782.00**	**57,593.00**
1	Total Number Other Personnel					Total Other Personnel Costs	**57,593.00**
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	**78,540.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
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SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2017	**12 / 31 / 2017**	**Project**	**1**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**1,000.00**
2. Foreign Travel	**13,300.00**
Total Travel Costs	**14,300.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**0.00**
2. Stipends		**0.00**
3. Travel		**0.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	Total Participant/Trainee Support Costs	**0.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
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SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2017	**12 / 31 / 2017**	**Project**	**1**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	**1,200.00**
2. Publication Costs	**0.00**
3. Consultant Services	**0.00**
4. ADP/Computer Services	**0.00**
5. Subawards/Consortium/Contractual Costs	**71,985.00**
6. Equipment or Facility Rental/User Fees	**0.00**
7. Alterations and Renovations	**0.00**
8. Other: **Other: Field research expenses in India**	**30,000.00**
9. Other:	**0.00**
10. Other:	**0.00**
Total Other Direct Costs	**103,185.00**

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	**196,025.00**

H. Indirect Costs

	Indirect Cost Rate (%)	**Indirect Cost Base ($)**	Funds Requested ($)
Modified Total Direct Costs	**48.50**	**72,284.00**	**72,284.00**
Cognizant Federal Agency: **Texas A&M AgriLife Research**		Total Indirect Costs	**72,284.00**

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	**268,309.00**

J. Fee

	Funds Requested ($)
Fee	**0.00**

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	**268,309.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
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SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2018	**12 / 31 / 2018**	**Project**	**2**

A. Direct Labor - Key Personnel

Name	Project Role	**Base Salary ($)**	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	**Fringe Benefits ($)**	Funds Requested ($)
Fleischman, Forrest	**PI_TYPE**	**7,930.00**	**1**			**8,410.00**	**2,192.00**	**10,602.00**
Kreuter, Urs	**CO-I**	**10,552.00**	**.25**			**2,794.00**	**670.00**	**3,464.00**
Rodriguez Solorzano, Claudia	**CO-I**	**5,416.00**	**1**			**5,744.00**	**1,717.00**	**7,461.00**
							Total Key Personnel Costs	**21,527.00**

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	**Post Doctoral Associates**	**12**			**43,065.00**	**16,006.00**	**59,071.00**
1	Total Number Other Personnel					Total Other Personnel Costs	**59,071.00**
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	**80,598.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050
Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2018	**12 / 31 / 2018**	**Project**	**2**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**1,000.00**
2. Foreign Travel	**11,000.00**
Total Travel Costs	**12,000.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**0.00**
2. Stipends		**0.00**
3. Travel		**0.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	Total Participant/Trainee Support Costs	**0.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050
Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2018	**12 / 31 / 2018**	**Project**	**2**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	**0.00**
2. Publication Costs	**0.00**
3. Consultant Services	**0.00**
4. ADP/Computer Services	**0.00**
5. Subawards/Consortium/Contractual Costs	**65,772.00**
6. Equipment or Facility Rental/User Fees	**0.00**
7. Alterations and Renovations	**0.00**
8. Other: **Other: Field research expenses in India**	**50,000.00**
9. Other:	**0.00**
10. Other:	**0.00**
Total Other Direct Costs	**115,772.00**

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	**208,370.00**

H. Indirect Costs

	Indirect Cost Rate (%)	**Indirect Cost Base ($)**	Funds Requested ($)
Modified Total Direct Costs	**48.50**	**69,160.00**	**69,160.00**
Cognizant Federal Agency: **Texas A&M AgriLife Research**		Total Indirect Costs	**69,160.00**

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	**277,530.00**

J. Fee

	Funds Requested ($)
Fee	**0.00**

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	**277,530.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050
Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2019	**12 / 31 / 2019**	**Project**	**3**

A. Direct Labor - Key Personnel

Name	Project Role	**Base Salary ($)**	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	**Fringe Benefits ($)**	Funds Requested ($)
Kreuter, Urs	**CO-I**	**7,930.00**	**1**			**8,662.00**	**2,237.00**	**10,899.00**
Fleischman, Forrest	**PI_TYPE**	**10,552.00**	**.25**			**2,878.00**	**685.00**	**3,563.00**
Rodriguez Solorzano, Claudia	**CO-I**	**5,416.00**	**1**			**5,917.00**	**1,748.00**	**7,665.00**
							Total Key Personnel Costs	**22,127.00**

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	**Post Doctoral Associates**	**12**			**44,357.00**	**16,236.00**	**60,593.00**
1	Total Number Other Personnel					Total Other Personnel Costs	**60,593.00**
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	**82,720.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050
Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2019	**12 / 31 / 2019**	**Project**	**3**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**1,000.00**
2. Foreign Travel	**3,750.00**
Total Travel Costs	**4,750.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**0.00**
2. Stipends		**0.00**
3. Travel		**0.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	Total Participant/Trainee Support Costs	**0.00**

PI Name : **Forrest Fleischman**	NASA Proposal Number
Organization Name : **Texas A&M AgriLife Research**	15-LCLUC15_2-0050
Proposal Title : **Impacts of afforestation on sustainable livelihoods in rural communities in India.**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2019	**12 / 31 / 2019**	**Project**	**3**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	**0.00**
2. Publication Costs	**0.00**
3. Consultant Services	**0.00**
4. ADP/Computer Services	**0.00**
5. Subawards/Consortium/Contractual Costs	**74,267.00**
6. Equipment or Facility Rental/User Fees	**0.00**
7. Alterations and Renovations	**0.00**
8. Other:	**0.00**
9. Other:	**0.00**
10. Other:	**0.00**
Total Other Direct Costs	**74,267.00**

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	**161,737.00**

H. Indirect Costs

	Indirect Cost Rate (%)	**Indirect Cost Base ($)**	Funds Requested ($)
Modified Total Direct Costs	**48.50**	**42,423.00**	**42,423.00**
Cognizant Federal Agency: **Texas A&M AgriLife Research**		Total Indirect Costs	**42,423.00**

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	**204,160.00**

J. Fee

	Funds Requested ($)
Fee	**0.00**

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	**204,160.00**

Proposal Title: Impacts of artificial afforestation on sustainable livelihoods in rural communities in India
A Step-2 proposal in response to NASA solicitation NNH15ZDA001N-LCLUC

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Scientific/Technical/Management Section

Proposal Title: Impacts of afforestation on sustainable livelihoods in rural communities in India: A Step-2 proposal in response to NASA solicitation NNH15ZDA001N-LCLUC.

Project Rationale

Artificial afforestation (afforestation hereafter) is a prominent part of an emerging architecture to offset increased anthropogenic carbon emissions as well as carbon sequestration capacity loss from deforestation and forest degradation under the United Nations Framework Convention on Climate Change (REDD+) (Agrawal, Nepstad, & Chhatre, 2011; Crouzeilles, et al., 2016; Menz, Dixon, & Hobbs, 2013; Suding, et al., 2015; The Bonn Challenge, 2016). Plantation forestry, established through artificial afforestation, also has the potential to reduce pressure on natural forests for providing industrial wood products (Pirard, Dal Secco, & Warman, 2016), improve water supply (Ilstedt, et al., 2016), and contribute to ecological restoration (Chazdon, 2014). Yet there is increasing global concern that some afforestation programs adversely affect the provision of a broader range of ecosystem services (Balthazar, Vanacker, Molina, & Lambin, 2015; Bremer & Farley, 2010; Calviño-Cancela, Rubido-Bará, & van Etten, 2012; Hall, Holt, Daniels, Balthazar, & Lambin, 2012; Menz, et al., 2013; Veldman, et al., 2015; Xu, 2011), including some that rural populations depend on for their livelihoods (Andersson, Lawrence, Zavaleta, & Guariguata, 2015; Gerber, 2011).

To date, there is little research documenting the distribution of livelihood impacts of afforestation programs and the mechanisms that influence these outcomes (Le, Smith, Herbohn, & Harrison, 2012). On the one hand, forests are known to play a vital role in the livelihoods of poor and vulnerable populations in developing countries by providing fuelwood, times, and other forest products (Angelsen, et al., 2014; Sunderlin, et al., 2005; Sunderlin, et al., 2008), and thus increasing the area covered by forests may enhance those livelihoods. On the other hand, afforestation programs often replace non-forest or degraded forest land covers that are important for rural livelihoods and/or plant species that are commercially valuable on international markets but produce few local benefits (Holt, Binford, Portier, & Vergara, 2016); they may also result in the loss of de-facto property rights by locals in favor of plantation owners in the government or large companies. For example, many people in developing countries derive income from livestock grazing which may be displaced by use restrictions or changing species compositions associated with plantations (Angelsen, et al., 2014; Chopra & Dasgupta, 2008a, 2008b; Jodha, 1986).

India is an important country to study because it has been a global leader in implementing afforestation programs since the 1970s. It implemented afforestation programs on an area equivalent to 10% of the country between 1950 and 2005 (Ravindranath, Murthy, Chaturvedi, Andrasko, & Sathaye, 2007), and it has a very large number of people who depend on degraded natural ecosystems who might be impacted by these efforts (Gundimeda & Shyamsundar, 2012; Jodha, 1986). It is also planning to expand its afforestation programs. The current government has proposed to allocate 6.2 billion U.S dollars to afforestation projects, with the goal of increasing the percent of India covered by forest from the current 21.34% to 33%, as part of India's Intended Nationally Determined Contribution to reducing greenhouse gas emissions under the United Nations Framework Convention on Climate Change (Balachandran, 2016). This proposal, like similar proposals from previous governments (e.g. Ministry of Environment and Forests, 2010), says little about the impacts of the proposed shift in land cover on rural

livelihoods. Evaluating the impact of afforestation in India will inform both global debates about the trade-offs involved in artificial afforestation programs as well as domestic debates within India about how best to improve environmental outcomes while also promoting rural prosperity.

Evaluations of afforestation programs in India and around the world have not examined their livelihood impact. Recent global evaluations of afforestation and reforestation programs have primarily focused on ecological as opposed to socioeconomic impacts (e.g. Crouzeilles, et al., 2016). Similarly, evaluations of afforestation programs in India have focused on evaluating impacts other than livelihoods. For example, afforestation programs failed to increase fuelwood supply (Agarwal, 1986; Misra & Bhatty, 1990; Saxena, 1994; Saxena & Ballabh, 1995), produce biofuel at a large scale (Ariza-Montobbio & Lele, 2010; Francis, Edinger, & Becker, 2005), generate income for poor rural households (Saigal, 2011; Saxena, 1994; Saxena & Ballabh, 1995), restore wastelands (Baka, 2013, 2014; Saigal, 2011), compensate for lost forests (Comptroller and Auditor General of India, 2013), or promote collective action towards forest regeneration (Poffenberger & McGean, 1996; Springate-Baginski & Blaikie, 2007; Sundar, Jeffrey, & Thin, 2001). At the same time, they are credited with contributing to stabilization of forest cover (Forest Survey of India, 2013; Tian, Banger, Bo, & Dadhwal, 2014) as natural forests and other land covers are being replaced by plantations (Davidar, et al., 2010; Puyravaud, Davidar, & Laurance, 2010a). Plantation failure rates are not well documented, but estimated to be very high (Bhargav & Dattatri, 2015; Comptroller and Auditor General of India, 2013; Maharasthra Forest Department, 2006, 2009, 2010). Most land-cover/land-use change (LCLUC) studies in India do not clearly differentiate between the effects of artificial afforestation programs and natural regeneration.

Project Objectives and Significance

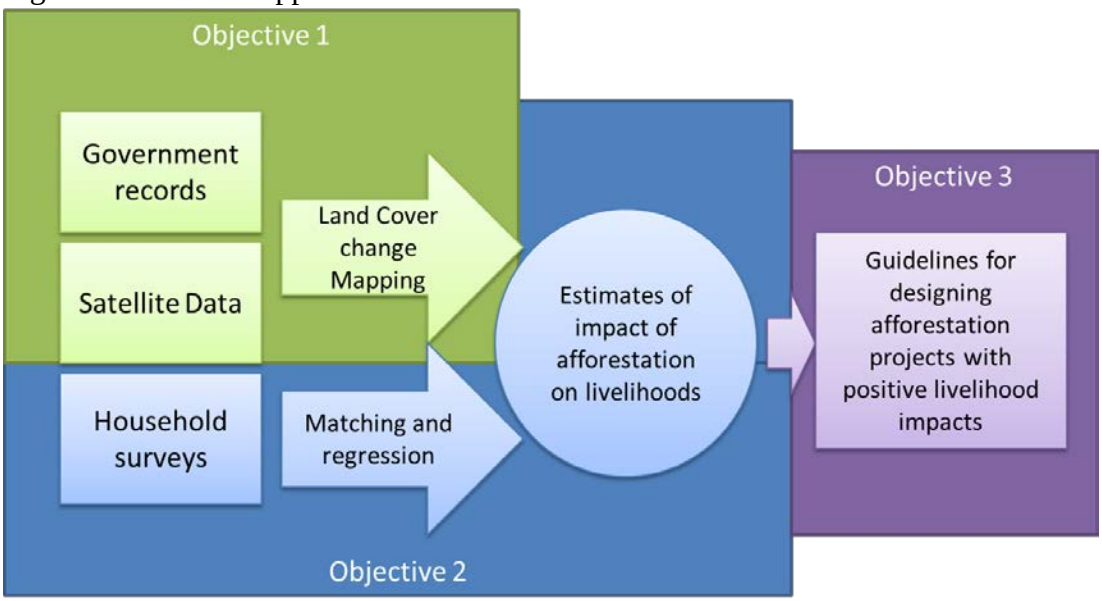
The overall goal of this project is to understand the impact of forest plantation activity on rural livelihoods. Artificial afforestation is widely applied as a policy tool in India and throughout the world, and the use of this tool is likely to increase in the future as a result of global climate agreements. As mentioned above, India is planning to spend billions of dollars in coming years on artificial afforestation (Balachandran, 2016), with the goal of afforesting more than 10% of India's land area. Few studies examine the impact of large-scale afforestation programs on land cover or on social conditions (Le, et al., 2012). Little is known about the factors that influence the success of afforestation programs or their social impacts. **Conducting an evaluation of the impact of artificial afforestation, as we propose, will provide crucial information to improve the design of future afforestation programs in India and around the world. This will help to align the imperative of carbon sequestration with the needs and interests of the poor.** One reason such evaluations have not been conducted in the past is the difficulty of obtaining data that enables measurement of the impact of long-term LCLUC on livelihoods. We will overcome this difficulty through a combination of government records, household surveys, and retrospective analysis of satellite data. In so doing, we will develop new tools that can be used by researchers around the world to track afforestation activities and measure their impacts on livelihoods.

In order to achieve our goal, we have identified three interlinked objectives. The linkages between these objectives are illustrated in figure 1, below:

1. **Measure the extent of LCLUC attributable to afforestation.**
2. **Measure the relationship between LCLUC attributable to afforestation and rural livelihoods.**
3. **Develop and publicize guidelines that link LCLUC to livelihoods in order to enable policy-makers to identify afforestation activities which will have the most positive impact on livelihoods.**

We will achieve these objectives by conducting a detailed case study of Kangra District, in the Himalayan foothills in the state of Himachal Pradesh. Afforestation has massively reshaped land cover in this state. Because of the structure of land ownership in India, the vast majority of afforestation is undertaken by state forest departments on public land. Data we obtained from the Himachal Pradesh Forest Department indicates that since 1950, the department has conducted afforestation on 10,753.27 km^2, which amounts to nearly 20% of the land area of the state, and 27% of the land area below treeline (the actual area affected may be less, as some areas may have experienced multiple rounds of afforestation). More recently, government afforestation projects were conducted on 2% of the land in Kangra district between 2005-2015. As described in more detail below, we will combine detailed government data on plantation activity in Kangra district between 2005 and 2015 with analysis of time series of Landsat imagery dating back to 1985 and 4,200 household livelihood surveys in 140 villages.

Figure 1: Research Approach.



Project Plan

Objective 1: Measure the Extent of LCLUC Attributable to Afforestation

In order to understand the impact of afforestation activities on livelihoods, we will first measure the impact of afforestation on land cover. This objective is both a step in our larger analysis as well as the source of two significant contributions of itself. First, we will develop a

methodology for utilizing widely available satellite datasets to detect afforestation activities across the wide range of ecosystems and plantation types present in Kangra district. This geographic information-processing methodology, while developed specifically for this region, may have broad utility for land-cover/land-use change (LCLUC) studies, including utilization of an advanced endmember-estimation algorithm. Second, a primary goal of all plantation programs is to achieve changes in land cover – yet although we know from government records that the amount of afforestation in the region has been massive, we do not know how the programs affect land cover because government records do not include long-term monitoring, nor do they provide details on land covers preceding afforestation. Thus, we do not know whether plantations in this region have replaced native forests or grasslands, as some biologists have claimed (Puyravaud, et al., 2010a; Puyravaud, Davidar, & Laurance, 2010b), or even whether they have succeeded in growing trees.

Our examination of land-cover impacts of afforestation will begin with an analysis of detailed records of government afforestation programs, which we obtained for Kangra District in the spring of 2016. This includes records of all 2252 plantations in Kangra district between 2005 and 2015, covering a total of 13645 ha. In our pre-proposal, we proposed to study three districts; however our obtaining these government data for one of our three original districts will enable us to conduct a much more accurate and detailed study than would be possible in other parts of India, where government agencies have historically been very reluctant to share data with researchers, and we have thus decided to focus on this one district. The PI, postdoc, and graduate student will work closely with our colleagues in the Himachal Pradesh Forest Department, led by Dr. Pushpendra Rana, to create a database of these government records, which will include information on the area and species planted, the cost of the plantation, and the government program which provided funding for the plantation. Although this will contain data on all species planted, we will particularly focus on the distinction between broad-leaved and coniferous species, as our preliminary data, described below, indicates that this distinction is particularly important for livelihoods. In most cases, spatial information in the database will at least include latitude and longitude for all sites stored in a point shapefile, the panchayat (the lowest administrative and political unit) the plantation was located in, and in some cases a verbal description and/or hand-drawn map, which we will digitize and store in a georeferenced polygon shapefile. We expect that creating this database will take 6 months, and will be the first task we pursue once funded.

We will ground truth the plantation data obtained from the government in a subsample of panchayats that we will select for deeper analysis. We will use the data on government plantations, combined with publicly available socioeconomic data from the Indian census to conduct propensity score matching to select 140 villages which differ in their exposure to plantation activity, but are otherwise similar in terms of social and ecological conditions. This matching strategy is integral to our measurement of livelihood impacts and is thus explained in more detail below in the section devoted to livelihoods. In order to take advantage of synergies in data collection efforts, as well as to insure that our socioeconomic analyses are based on the most accurate measurements of plantations, we will conduct ground truthing in these same 140 villages, using locally hired teams under the direct supervision of the postdoc,PI Fleischman, Co-PI Güneralp, and our Indian partners who already have active research in the district.

We will use satellite imagery, land-use maps, published and unpublished archives, including the data in our database, and interviews with local key informants, to map afforestation dynamics in the district from 1985 to 2015. This time period captures most afforestation that has

occurred in India (Ravindranath, et al., 2007), and allows us to draw on 30-m spatial resolution Landsat TM/ETM+ data covering this period. We will use anniversary-/near-anniversary-date Landsat imagery at 5-year intervals and a novel image endmember-extraction algorithm (EEA) based on machine learning (Filippi & Archibald, 2009; Schneider, 2012) and spectral unmixing (Shi & Wang, 2014) to examine the extent of afforestation, and to identify those land-cover types being replaced by afforestation in Kangra (Landsat path 148, row 38). The challenge here is in identifying the extent of individual plantations, many of which are smaller than 5 ha, and tracking their change over time (i.e., previous LCLUC before the establishment of the plantation and change in tree species composition afterward) using Landsat data. To overcome this challenge, we will utilize a cutting-edge image endmember-estimation algorithm and spectral unmixing to map fractional abundances of various land-cover classes (e.g., tree plantation types, at varying levels of maturity/age), in combination with contextual algorithms. Available EEAs assume that, for each endmember, there exists at least one pure pixel within the image, which is an assumption that is often invalid. This limitation does not apply to the semi-autonomous Support Vector Machine-Based Endmember Extraction (SVM-BEE) algorithm (Filippi & Archibald, 2009), as it is able to estimate endmembers from the data. This advanced algorithm was originally applied to the analysis of hyperspectral imagery, and it has been shown to be promising in applications with medium spatial-resolution imagery (Filippi & Archibald, 2009; Filippi, Archibald, Bhaduri, & Bright, 2009). However, its performance on low-dimensional/multispectral imagery (e.g., Landsat TM/ETM+ images), has never been tested in an actual application setting.

SVM-BEE (Filippi and Archibald, 2009) uses Support Vector Machines (SVMs) on small subsets of the data in an iterative procedure to identify endmembers. An attractive feature of SVM-BEE for our purposes is that the number of SVM-BEE-estimated endmembers is not constrained by the number of bands + 1 upper limit on endmembers that applies to other EEAs. This makes SVM-BEE particularly useful for mapping greater numbers of materials with multispectral data such as Landsat imagery, relative to other EEAs. We will use mixture-tuned matched filtering (Boardman, 1998) and other algorithms (Chang, 2003) to accomplish spectral unmixing for material fractional abundance-determination. The derived fractional-abundance maps, the Landsat image bands themselves, and other ancillary data (e.g., vegetation indices) will be used as input to contextual/geospatial object-based image analysis (GEOBIA) algorithms (e.g. Benz, Hofmann, Willhauck, Lingenfelder, & Heynen, 2004) to exploit the relatively homogeneous and regular spatial-spectral characteristics of the tree plantations, relative to surrounding/proximal natural forest areas (Petersen, et al., 2016).

The ***overall goal*** of this component of the proposed research is to deploy the SVM-BEE algorithm—with and without GEOBIA—for detecting and mapping various vegetation types, in particular, broad-leaved and coniferous tree plantations, at the sub-pixel level, which is very challenging using current methods. The ***overall hypothesis*** is that the SVM-BEE algorithm can significantly more accurately detect different vegetation/tree plantation types than existing EEAs based on multispectral Landsat images, and that the addition of GEOBIA may further increase detection/mapping accuracy. The ***rationale*** of this portion of the proposed study is that SVM-BEE will make it possible to identify many types of differences among vegetation types, and in particular, the tree plantation types of interest identified above, within multispectral images. We plan to test our overall hypothesis by pursuing the following ***specific aims***: 1) for the tree plantations of interest, quantitatively compare the accuracy of SVM-BEE-estimated *multispectral* image endmembers against those derived from conventional EEAs. All image

endmembers will be quantitatively compared with resampled spectra in *in situ* vegetation spectral libraries developed via a compact hyperspectral field spectroradiometer, to-be-collected by Co-PI Güneralp, and fractional-abundance/classification maps will be compared with ground-reference and ancillary data; 2) for an image-acquisition date coincident with Güneralp's field visit, for comparative purposes, test performances of EEAs (as noted above) on hyperspectral EO-1 Hyperion imagery; and 3) conduct tree plantation mappings with and without GEOBIA and quantitatively assess. *This contribution is expected to yield a cutting-edge image endmember-estimation analysis for the purpose of vertically enhancing our ability to detect and identify tree plantation types using widely and freely available medium-resolution Landsat data.*

We will then use SVM-BEE, with and without GEOBIA, to produce LCLUC maps for the district from 1985 to 2015, at 5-year intervals which estimates the total area afforested using Landsat data, as well as changes in the land cover that can be attributed to afforestation as opposed to other activities, such as natural regeneration. Combining these data with household locations recorded in surveys (described below) will enable us to construct estimates of the exposure of individual households to afforestation.

Objective 2: Measure the relationship between LCLUC attributable to afforestation and rural livelihoods.

The second objective of this project is to measure the influence of afforestation activities on household livelihoods. While the dependence of the rural poor on forests is well documented, both in India and globally (Angelsen, et al., 2014; Chopra & Dasgupta, 2008a, 2008b; Jodha, 1986), we know little about the relationship between afforestation and livelihoods. As described above, combining government data with remote sensing will enable us to produce LCLUC maps that will enable us to measure the exposure of both villages and individual households to afforestation. We will use propensity score matching to select 140 villages in which to conduct household livelihood surveys. In these surveys, we will collect information on household livelihoods, including use of forests, as well as on several variables that our preliminary data lead us to believe have an influence on the relationship between afforestation and livelihoods. We will then use regression and matching techniques to analyze the impact of afforestation, measured through remote sensing, on livelihoods, as measured through surveys.

Preliminary fieldwork, including interviews conducted by our Indian partners Harry Fischer and Pushpendra Rana with 60 households in 6 villages in April-May of 2016, indicate that the impacts of afforestation on rural livelihoods is complex, with effects varying across measures of livelihoods, the livelihood strategies of different households, and the time frames examined. As a simple example, a pine plantation on land that was previously used for open grazing may, as it matures and the unpalatable pine shades out palatable grasses and broad-leafed shrubs, force a family to travel farther to graze their livestock, or purchase fodder in the market. This may contribute to a long-term decision to reduce livestock, as a direct effect from the plantation. This may lead to cascading indirect effects on livelihoods: cattle supply fertilizer (from dung) and power for plowing, thus decreased cattle ownership will cause farmers to increase capital expenditures on fertilizer and machinery, which may in turn lead some households to invest in alternative production activities or off-farm employment. The nature of these indirect impacts on households will depend on households' assets and vulnerabilities, (Bebbington, 1999).

Dependent Variable: Household livelihoods

The primary outcome of interest in this study is household level livelihoods, and this will be the main focus of our household surveys. Because rural livelihoods are complex (Bebbington, 1999; Ellis, 2000), we will measure forest and environmental incomes (Angelsen, et al., 2014), agricultural income, and income earned through off-farm employment, as well as asset-based measures of well-being (Krishna, 2010). We will draw on techniques that have been used by members of our team in the past, including those developed by the International Forestry Resources and Institutions program (Chhatre & Agrawal, 2009; Coleman & Fleischman, 2012; Persha, Agrawal, & Chhatre, 2011; Persha, Fischer, Chhatre, Agrawal, & Benson, 2010), the Center for International Forestry Research (Angelsen, et al., 2014), and the Revitalizing Rainfed Agriculture Research Node (Fischer & Chhatre, 2016). Our preliminary research indicates that some households are significantly more vulnerable to livelihood changes resulting from afforestation. Thus, we will pay particular attention to examining differential impacts on households that are vulnerable due to their poverty, low caste status, or high dependence on forest or grazing-based incomes.

Independent Variables: Characteristics of Afforestation Policy.

We propose to measure the effect of afforestation policy on rural livelihoods; however, afforestation programs differ significantly along a number of dimensions. Therefore, we propose to measure exposure to and type of afforestation policy along a number of dimensions:

1. **Afforestation Exposure**: Exposure refers to the amount of afforested land near a household. We account for this in two ways. First, we create a buffer around each household indicating areas that they could feasibly access. We then record the amount of afforested land lying within the household buffer according to our LCLUC maps generated as described above in objective one. We will ensure our results are robust to the size of the buffer, and will also examine the sensitivity of our results to including plantations of different ages. Second, we will measure the total forested area within the buffer, again using the datasets generated in objective one, and the percent of it that is the result of afforestation. This will help us to control for the possibility that afforestation has greater impacts on livelihoods in areas where less total forest is present.
2. **Plantation Types:** As previously mentioned, afforestation programs in India vary in terms of the types of species being planted. The LCLUC maps generated as described in objective one will provide measures of the exposure of households to broad-leaved and coniferous plantations. Our preliminary data indicates that broad-leaved species appear to be more useful for fodder and firewood than *Pinus roxburghii*, the main conifer planted in this region. Two products derived from forests are of particular importance for livelihoods in this region: fuelwood and fodder. Fodder can include both lopped branches of palatable species, as well as grass growing in forests, degraded forests, and open grasslands. Plantations of broad-leaved species, can increase fuelwood supplies, but restrictions on harvest during early years may lead to short-term decreases in fuelwood supplies (Agarwal, 2001). Plantations can also provide fodder through palatable broad-leaved species; however, they are often placed in grasslands or degraded forest areas where grass was formerly abundant, and trenches and fences built for plantations may prevent animals from grazing in their former pastures. By contrast, plantations of *Pinus roxburgh* appear in our preliminary data to decrease the supply of all forest products to most households. Pines are planted because they are commercially

valuable for sawtimber and pulpwood; however, because forests are government owned, and because commercial harvests have been banned in Himachal Pradesh since 1986, benefits from these plantations only come to those involved in illegal timber harvesting, who are usually wealthy merchants from nearby towns (Robbins, 2000a, 2000b, 2003; Robbins, McSweeney, Chhangani, & Rice, 2009; Vasan, 2002).

3. **Collaborative Management:** A large literature, some based on field studies in Himachal Pradesh and/or conducted by members of our project team, finds that collective action and public participation in decision-making play a crucial role in the success of public programs generally, and forest programs in particular (Agrawal & Chhatre, 2006, 2007; Chhatre & Agrawal, 2008; Coleman, 2009; Ostrom, 1990; Persha, et al., 2011; Rodriguez-Solorzano, 2014). However many formally participatory programs in India do not effectively lead to village-level collective action (Lélé, 2005; Springate-Baginski & Blaikie, 2007; Sundar, 2000; Sundar, et al., 2001), and many studies of collective action do not include robust measures of livelihoods (Hajjar, et al., 2016). We will examine the livelihood impacts of formal participatory programs by using our government data to identify which plantations in our study panchayats were the result of formal participatory programs. We will also measure the impact of actual collective action (whether the result of government programs or autonomous action) on plantation success and livelihood impacts at the panchayat level. Finally, we will measure whether the participation of individual households in collective action influences the benefits they receive from afforestation activities. We will measure individual involvement in collective action using techniques developed in recent research by team members (Fischer, In Press; Fleischman & Rodriguez-Solorzano, in review).

This model implies a set of hypothesized relationships between afforestation programs with different characteristics and rural livelihoods, and separately for vulnerable households. Table 1 briefly presents the hypothesized relationships between each of these variables for the entire sample and for the subgroup of vulnerable households.

Table 1. Hypothesized relationship between each independent variable and livelihood improvement.

Variable		Full Sample	Vulnerable Households
Afforestation Exposure			
	Percent Afforested	+	-
	Village Size	+	+
	Road Access	+	+
Plantation Species			
	Pinus, Eucalyptus, Populus	-	-
Collaborative Management			
	Planning	+	+
	Implementation	+	+
	Monitoring	+	+

Data Collection and Analysis:

The ideal way to measure these changes would be to track individual households' livelihood trajectories over long-time frames, as they react to changes in land cover that we can

observe in historical satellite data. However it is difficult for households to retrospectively reconstruct detailed livelihood histories (Krishna, 2010), so we will use two alternative techniques. First, we will ask households to identify, using images generated from recent satellite imagery, how they use different parcels with distinct land covers near their homes. This will enable us to compare the current uses of different land covers by households with different livelihood strategies to understand what kinds of households may benefit – or lose out when land covers change. However, this strategy is limited because although it will identify direct effects on livelihoods, it will not enable us to measure the complex interactions, described above, which mediate the impact of a single change in land cover on a household's complex livelihood strategy.

Thus, our second strategy will be to use propensity score matching and regression to make comparisons between households within panchayats that are exposed to different levels and types of plantation activity. Panchayats are the basic unit of local government in India, roughly equivalent to a town in the United States. There are 751 panchayats in Kangra district, and we will select 140 of these in which to conduct household surveys. We will conduct our ground-truthing in the same 140 panchayats, allowing us to take advantage of synergies between different elements of field work, as well as insuring that our most accurate, ground-truthed data on afforestation will be used in the analysis of livelihoods.

In order to conduct the propensity score matching, we will combine data from our government records, which tell us the panchayat in which every plantation from the last 10 years was undertaken and will be completed before we begin fieldwork, with census data and other government records. As mentioned above, our preliminary research indicates that the impact of plantations on livelihoods depends particularly on the species planted: in particular, broad-leaved deciduous species are likely to have more positive livelihood impacts than pine. Thus, we will match across four categories: panchayats (a) with no forested land, (b) with natural forests, (c) with plantations that contain deciduous broad-leaf species, and (d) with plantations that contain coniferous species. Across these categories, villages will be matched according to landscape conditions, including altitude, slope, aspect, and other land use types (e.g. grazing land) as well as socio-economic characteristics including population, caste composition, and accessibility to major roads and population centers.

Within each panchayat we will conduct surveys in 30 households selected randomly from a verified list of residents obtained from the panchayat office, stratified by whether or not the household is officially below the poverty line. Village authorities retain a list of households that are below the poverty line for the purpose of determining eligibility for social welfare schemes, and this is the best available a priori means of identifying households that are poor and thus likely to be more vulnerable to shifts in the availability of goods from forests (Fischer & Chhatre, 2016). Because use of forest products varies according to gender in South Asia (Agarwal, 2010), we will interview both male and female household members about their use of forests and other elements of their livelihoods. We will also collect data about poverty, asset ownership, access to livelihood alternatives, productive assets and human capital, and participation in decision-making related to forest land use, along with other control variables. In addition, we will conduct qualitative interviews with key players involved in various aspects of forest use and management, including members of user committees, forest guards, and current and former village leaders, to understand how collective action has influenced forest management.

Village-level surveys will be conducted by teams of two locally hired field assistants, and will begin in the sixth month of the project, continuing until the end of the second year. Our preliminary field work in April 2016 indicates that a team of two can conduct 30 household surveys, as well as key informant surveys, in 2 weeks, with an additional week allowed for ground truthing. Thus, each team can complete both ground truthing and survey field work in 3 villages in 2 months. 6 teams will be able to complete surveys in 144 villages, 4 more than needed, in 16 months (months 6-22 of the project), with 2 extra months remaining in the second year which can be used, if necessary, to make up any unexpected delays in field work, or to begin data cleaning and analysis. We will hire experienced teams of field workers who have worked on projects with our Indian collaborators in the past, and will also look for synergies between data collected in these past efforts, including extensive household livelihood surveys in Kangra district, and our own efforts.

Our prospectively matched villages will enable us to compare livelihood effects between villages that are exposed to different treatments. We will also use post-facto propensity score matching of households to compare household livelihoods between households that are similar except for their exposure to different kinds of afforestation activity. Finally, we will use regression techniques to make controlled comparisons across households to understand the effects of household characteristics on livelihood impacts.

Objective 3: Develop and publicize guidelines that link LCLUC to livelihoods in order to enable policy-makers to identify afforestation activities which will have the most positive impact on livelihoods.

The final objective of our research is to provide guidelines for policy makers, which will help them to assess the impact of decisions on rural livelihoods. These guidelines will be based on our analyses performed above, addressing the effects of afforestation programs on land cover and rural livelihoods, including the livelihoods of vulnerable populations, and providing estimates of overall economic impacts. As discussed above, many afforestation programs fail to achieve the simplest goal of establishing tree cover, thus the guidelines will identify biophysical and institutional factors that contribute to successful plantation establishment. Furthermore, the guidelines will address the differentiated impacts of different kinds of plantations on different human populations, helping policy-makers select plantation programs with greater potential to improve livelihoods.

Although we will publish our guidelines, along with other outcomes of our research, in internationally recognized peer-reviewed journals, these are not widely available in India, and are thus not accessible to policy-makers. Thus, during the third year of our project we will invest substantial time and energy in an outreach strategy in India. The outreach strategy will target two types of decision-makers (Fleischman, 2014): First, we will target people responsible for the design and funding of plantation programs, who are primarily located in Delhi and state capital cities, and include not only high-ranking foresters, but also politicians, donors, and leaders of major NGOs and scientific organizations. We will reach these individuals by publishing our research in *The Economic and Political Weekly*, the most widely read social science and policy publication in India, and by conducting targeted workshops in Delhi, Shimla (the capital of Himachal Pradesh), and other major cities where donors, NGOs, and scientists are concentrated (likely Bangalore and/or Hyderabad). Our co-investigators in India have agreed to use their experience as high-ranking foresters (Rana) and their connections at one of India's elite business

schools (Chhatre and Fischer) to assist us in identifying key decision-makers and providing access to workshop venues.

Second, as officials have substantial discretion in the field implementation of plantation programs, we will reach out to field-level forestry officials through publications in the widely read *Indian Forester* as well as workshops with field officials at venues in Kangra, Shimla, and similar forest areas in neighboring districts and states. Again, Co-I Rana will assist us in identifying locations and encouraging participation in these workshops.

Responsiveness to NASA Solicitation

The solicitation calls for the integration of innovative analyses of land system dynamics with meaningful social science research with a special focus on South Asia. Our proposed research satisfies these criteria in three ways. First, we propose to use an innovative set of techniques to detect LCLUC using *in situ* ground data and Landsat data. Specifically, we will use a novel image endmember-extraction algorithm based on machine learning and spectral unmixing to identify land-cover changes resulting from plantations that would be too small to detect using more traditional analytical tools. Doing so will enable us to test the value of the semi-autonomous Support Vector Machine-Based Endmember Extraction algorithm (Filippi & Archibald, 2009) for analysis of low-dimensional/multispectral imagery (e.g., Landsat TM/ETM+ images) and develop techniques that can be utilized by other researchers to identify similar LCLUC.

Second, our research is driven by fundamental social science questions about the impact of public policies on the relationship between land cover and livelihoods. Countries around the world are using afforestation as a tool to satisfy their commitments under global climate agreements, yet there is little evidence of the impacts of these activities on livelihoods. We will measure the impacts of afforestation on livelihoods in one district in India, providing evidence about factors that may determine the impacts of afforestation activities around the world. In particular, while research on the management of natural resources shows that local collective action is often crucial for successful management, this theory has not been tested in the context of afforestation, and our data will enable us to measure the impact of village-level collective action on both plantation success and livelihood outcomes.

Third, our research aims to develop actionable science relevant to the contemporary South Asian context. India's government is proposing to spend billions of dollars in coming years on afforestation, with the goal of converting more than 10% of the country's area to forest from other land covers. Measuring the impact of afforestation on livelihoods will enable us to develop guidelines that will help Indian policy-makers minimize potential negative impacts of afforestation activities on rural livelihoods. Furthermore, we will take steps beyond the usual scientific publications, including publishing in venues widely read in India and conducting workshops in collaboration with our local partners, to help Indian policy-makers design better afforestation policies based on our research.

Finally, our proposal is also responsive to the solicitation's emphasis on international collaboration. We will work closely with our regional science partners in India who have extensive experience studying the vulnerability of the rural poor and the implementation of government afforestation programs. Our co-investigators in India have existing research agendas on forest management and social vulnerability, and existing research and management responsibilities in Kangra district, insuring close collaboration between our teams.

Project Management

Our team brings together a set of researchers with strong complementarities in their research skills. PI Fleischman has more than 2 years of field research experience studying forest management in India, much of it with a focus on plantation management (Fleischman, 2014), as well as experience managing large interdisciplinary teams. Co-PI Güneralp has experience in land-change analysis and remote-sensing strategies that we will apply in this case, and will be assisted by Co-I Filippi, who developed some of the algorithms we propose to use. Co-PI Coleman is an econometrician with extensive experience analyzing household and village-level datasets in developing countries to understand policy impacts in the forest sector. Co-Investigator Rodriguez Solorzano is an expert in the design of household questionnaires for studying social vulnerability, while Co-Investigator Kreuter brings expertise in analysis of rural economies. Our Indian co-investigators include Ashwini Chhatre, a world recognized expert in the study of collective action, vulnerability, and forest livelihoods, with more than a decade of fieldwork experience in Himachal Pradesh, along with Chhatre's postdoc Harry Fischer, who has extensive field experience in Kangra district, and Chhatre's former student, Pushpendra Rana, who is now a high ranking forester in Kangra district.

We will use two strategies to insure effective coordination across livelihood surveys and remote sensing, as well as across field data collection and office-based analyses. First, our project is built around a small team of researchers centered at one university, Texas A&M. We have built strategic connections to one researcher at Florida State which the PI has worked closely with in the past (Coleman & Fleischman, 2012), and with a research group in India with a closely allied research agenda and an ongoing research program located in the same district.

Second, we have clearly delineated project responsibilities. PI Forrest Fleischman will be responsible for overall project coordination as well as survey design and supervising all work on the livelihood surveys, as well as ground truthing, which will involve co-Is Rodriguez Solorzano, Coleman, and Kreuter. Within the livelihood survey component, Coleman will be responsible for research design (i.e. implementing the matching strategy described above), Rodriguez Solorzano will be responsible for questionnaire design and field implementation, and Kreuter will be responsible for economic analysis of livelihoods. Co-I Güneralp will be responsible for conducting and coordinating remote-sensing analysis, including conducting the field work to collect *in situ* ground-truthing data. Co-I Filippi will provide technical assistance in remote-sensing analysis. A postdoc will be hired to work full-time on the project, and will be involved in all aspects of data collection and analysis, further facilitating exchange in project components – in fact this is one reason we opted for a postdoc rather than hiring separate graduate students to focus on different project components. Güneralp will hire a graduate student to assist in data processing for remote sensing analysis.

Our working relationships in India are similarly built strategically to facilitate project management. We have selected to work with collaborators in India who have highly relevant expertise and current work assignments, which will facilitate our collaboration. The existing research program of Ashwini Chhatre and Harry Fischer has substantial theoretical and practical overlaps with the research we have proposed. Chhatre is associate professor of public policy at the Indian School of Business in Hyderabad, one of India's most distinguished business schools, and is the director of the research node of the Revitalizing Rainfed Agricultural Network, where Fischer is a postdoc. Both Chhatre and Fischer have extensive field research experience in Kangra district. Research at the Research Node focuses on linkages between land use and livelihoods, and we will be drawing on methods they have developed to evaluate livelihoods and

vulnerability (Fischer & Chhatre, 2016). We will consult extensively with Chhatre and Fischer in the design and implementation of our field research program, and expect to also draw on their extensive knowledge of the district in preparing joint publications. Our third collaborator, Pushpendra Rana, completed his PhD under the supervision of Chhatre in 2014, and has returned to his job as a member of the Indian Forest Service with the government of Himachal Pradesh, where he currently serves as Project Director for the Himachal Pradesh Forest Ecosystem Climate Proofing Project in Kangra District. He has extensive experience implementing forest plantation programs in the region, and has close contact with decision-makers. As such, we will work with him to obtain relevant government data (i.e., records of plantations) as well as to effectively share our results with key decision-makers within the department. All three Indian co-investigators also have extensive datasets on land use and livelihoods in Kangra, and we will leverage this data with our own to extend our analyses.

Tentative Schedule:

Year 1:

Upon obtaining funding, our first task will be to begin constructing the database of afforestation projects, based on government records. We have already obtained most of the government records necessary for this stage, and we will work with Pushpendra Rana from the Himachal Pradesh forest department to obtain further records if these are necessary. The database will be designed by Fleischman & Güneralp, and data entry will be performed by the postdoctoral associate and graduate student budgeted for the project. The data on plantations will be merged with village level census data into a spatially explicit dataset that identifies the locations of plantations of different types, as well as socioeconomic variables for the panchayats in which the plantations occur. This will be used for selecting matching panchayats, using propensity score matching, as described above. Propensity score matching will be conducted by Coleman, Chhatre, and Fischer. At the same time Rodriguez Solorzano will lead the development of the household questionnaire, with assistance from the 3 Indian Co-Is, Kreuter, and Coleman.

The entire team will visit Kangra during month 6 of the project to begin the field component of the study. We will hire a team of 12 local survey enumerators and 2 supervisors who will be responsible for conducting both ground truthing and household surveys in the villages they visit. We will rely on existing networks of research assistants that Chhatre, Fischer, and Rana have hired for previous research projects in Kangra. During this month, we will field test the survey instrument and train the field assistants. The postdoc will remain for 2 more months to supervise the field team and deal with any unexpected problems that may arise. We expect that teams of 2 enumerators will spend 3 weeks in each village. Thus, completing surveys in 140 villages with 6 teams of enumerators will take 16 months. We will use tablet-based questionnaires for household surveys, insuring rapid and reliable uploading and backing-up of data.

Year 2:

As suggested above, field surveys will continue during year 2 up until the 22nd month of the project. Fleischman, Rodriguez Solorzano, and the postdoc will make staggered visits to the field site during this time to provide supervision, while the Indian co-Investigators will make frequent visits as well. As soon as sufficient ground-truthed data becomes available, Güneralp and Filippi will begin conducting remote sensing analysis with assistance from the budgeted

post-doc and graduate student. Once all field data is available, all members of the team will work collaboratively to clean field data and begin analyses.

Year 3:

As all data will be collected by this time, year 3 we will focus on data analysis and preparing publications. In addition, team members Coleman and Fleischman will visit India in the final months of year 3 to present results in collaboration with the Indian Co-Investigators.

Topic:	**Year 1**	**Year 2**	**Year 3**	Leader
Assembling government plantations database				Fleischman, Güneralp, Rana
Household surveys				Fleischman, all collaborators
Ground-truthing				Güneralp, all collaborators
Analysis of satellite data				Güneralp, Filippi
Analysis of socio-economic data				Coleman, Fleischman
Preparation of publications, presentation of results in India				All team members

Expected outcomes and proposed deliverables

Our proposed research will generate several products. These will include datasets, analytic methods, peer-reviewed publications in high impact international journals focused on remote sensing, rural livelihoods and development, and social-ecological systems, publications in policy-relevant Indian journals, and workshops with key stakeholders in India. Specifically, we will produce the following products:

- Accurate fractional-abundance products derived from a novel image endmember-estimation algorithm and spectral unmixing algorithms on medium spatial-resolution remote-sensing data (i.e., Landsat).
- Tests of the validity of the Support Vector Machine-Based Endmember Extraction (SVM-BEE) algorithm for detecting changes in land cover derived from afforestation in Landsat data.
- LCLUC maps of Kangra District.
- A dataset of government plantation data in Kangra District between 2005 and 2015
- A dataset measuring household livelihoods in 4200 households in 140 villages in Kangra district.
- Improved scientific understanding of the impacts of artificial afforestation on rural livelihoods.
- Peer-reviewed publications in highly ranked multi-disciplinary journals, such as Global Environmental Change, World Development, Remote Sensing of Environment, Frontiers in Ecology and the Environment, and Geoforum.
- Publications in *Economic and Political Weekly* and *Indian Forester*, two publications with significant readership among policy makers and field foresters in India.
- A series of workshops conducted in collaboration with Indian partners in Himachal Pradesh, Delhi, and other major Indian cities.

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Xu, J. (2011). China's new forests aren't as green as they seem. *Nature News, 477*, 371-371.

Biographical Sketches:

Principal Investigator: Forrest Fleischman

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PROFESSIONAL PREPARATION

Dartmouth College	Environmental Studies	Postdoc, 2012-2013
Indiana University Bloomington		Public Policy PhD, 2012
Stanford University	Earth Systems	MS, 2003
Stanford University	Earth Systems	BS, 2003

ACADEMIC AND PROFESSIONAL APPOINTMENTS

2013 – Present *Assistant Professor,* Ecosystem Science & Management, Texas A&M University
2012-2013 *Research Associate,* Environmental Studies, Dartmouth College
2007-2012 *Research Assistant,* Workshop in Political Theory & Policy Analysis, Indiana University, Bloomington
2004-2006 *Policy Advocate,* Forest Service Employees for Environmental Ethics, Eugene, OR

MOST RELATED PUBLICATIONS

Fleischman, F. In Press. Understanding India's forest bureaucracy: a review. *Regional Environmental Change*.

Fleischman, F., & Briske, D. D. 2016. Professional ecological knowledge: an unrecognized knowledge domain within natural resource management. *Ecology and Society*, 21(1).

Fleischman, F. 2014. Why do Foresters Plant Trees? Testing Theories of Bureaucratic Decision-Making in Central India. *World Development* 62:62-74.

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Coleman, E. A., & **Fleischman, F**. 2012. Comparing Forest Decentralization and Local Institutional Change in Bolivia, Kenya, Mexico, and Uganda. *World Development* 40(4): 836-849

OTHER SIGNIFICANT PUBLICATIONS

Cox, M., S. Villamayor-Tomas, G. Epstein, L. Evans, N.C. Ban, **F. Fleischman,** M. Nenadovic, G. Garcia-Lopez. In Press. Formalizing theories of sustainability science. *Global Environmental Change.*

Fleischman, F., Ban, N. C., Evans, L. S., Epstein, G., Garcia-Lopez, G., & Villamayor-Tomas, S. 2014. Governing large-scale social-ecological systems: Lessons from five cases. *International Journal of the Commons,* 8(2).

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Description of scientific, technical and management performance on relevant prior research efforts

Dr. Fleischman has spent more than 2 years in the field in India (on five separate trips) conducting research on forest management and land use change, and has an extensive network of contacts in the forest policy world in India. In addition he has extensive prior experience coordinating and managing large interdisciplinary teams, including as a policy advocate with Forest Service Employees for Environmental Ethics, where he coordinated a large network of US environmental advocacy organizations, and as a postdoc, where he coordinated an interdisciplinary team of 14 researchers on 4 continents who collectively created the Social-Ecological Systems Meta-Analysis Database. In addition to past research on forest policy, Dr. Fleischman has experience conducting research on rural livelihoods and local collective action, key elements of this proposal.

Co-Investigators

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ACADEMIC APPOINTMENTS

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August 2007 – July 2015: Assistant and Associate Professor, Department of Geography and Geographic Information Science, University of Illinois at Urbana-Champaign.

September 2006 – July 2007: Giorgio Ruffolo Post-doctoral Fellow in Sustainability Science, Center for International Development, Kennedy School of Government, Harvard University.

MOST RELATED PUBLICATIONS

Persha, Lauren, Arun Agrawal, and Ashwini Chhatre (2011). Social and Ecological Synergy: Local Rulemaking, Forest Livelihoods, and Biodiversity Conservation. ***Science*** 331: 1606-1608.

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Agrawal, Arun, Ashwini Chhatre, and Elisabeth Gerber (2015). Motivational Crowding in Sustainable Development Interventions. ***American Political Science Review*** 109(3): 470-487.

Robbins, Paul, Ashwini Chhatre, and Krithi Karanth (2015). Political Ecology of Commodity Agroforests and Tropical Biodiversity. ***Conservation Letters*** 8(2), 77–85.

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Chhatre, Ashwini, and Vasant Saberwal (2005). Political Incentives for Biodiversity Conservation. ***Conservation Biology*** 19(2): 310-317.

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PROFESSIONAL PREPARATION

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Utah State University, Logan, UT, Political Science and Economics, B.A., 2003.

APPOINTMENTS

Associate Professor, Florida State University, 2015-present .
Assistant Professor, Florida State University, 2009-2015.
Research Assistant, Indiana University, 2004-2009.

MOST RELATED PUBLICATIONS

Coleman, E., & Mwangi, E. (2015). Conflict, Cooperation, and Institutional Change on the Commons. *American Journal of Political Science, 59(4),* 855-865.
Coleman, E. (2014). Behavioral Determinants of Citizen Involvement: Evidence from Natural Resource Decentralization Policy. *Public Administration Review, 74,* 642-654.
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Coleman, E. A., & Steed, B. (2009). Monitoring and Sanctioning in the Commons: An Application to Forestry. *Ecological Economics, 68(7),* 2106-2113.

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PROFESSIONAL PREPARATION

Kansas State University	Geography	BA, 1995 (*summa cum laude*)
University of South Carolina	Geography	MS, 1998
University of South Carolina	Geography	PhD, 2003

ACADEMIC AND PROFESSIONAL APPOINTMENTS

2010-Present	Associate Professor, Geography, Texas A&M University
2003-2010	Assistant Professor, Geography, Texas A&M University
2005-2008	Oak Ridge National Laboratory (ORNL) Faculty Fellow, June-August 2005-2008
2002-2003	Visiting Assistant Professor, Geography, Texas A&M University
2002	Consultant, Westinghouse Savannah River Company, DOE Savannah River Site
1999-2003	NASA Graduate Student Researchers Program (GSRP) Fellow
1998	Office of Naval Research (ONR) / NASA Fellow, Optical Oceanography
1994-1995	GIS Spatial Analysis Laboratory State Soil Survey GIS Analyst, Kansas State University

SELECTED PUBLICATIONS

Güneralp İ, **Filippi AM**, and Randall J (2014), Estimation of floodplain aboveground biomass using multispectral remote sensing and nonparametric modeling. *International Journal of Applied Earth Observation and Geoinformation* 33: 119-126, http://dx.doi.org/10.1016/j.jag.2014.05.004.

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PROFESSIONAL PREPARATION

University of Illinois at Urbana-Champaign, PhD. Geography, 2014
University of Illinois at Urbana-Champaign, MA. Geography, 2010
Maryville University Saint Louis, BFA, Fine Arts, 2006

ACADEMIC AND PROFESSIONAL APPOINTMENTS

2014 – Present Postdoctoral Research Fellow in Public Policy, Indian School of Business, Hyderabad India to work on *Revitalizing Rainfed Agriculture Network* and CIFOR's *Sentinel Landscapes project.*

PUBLICATIONS

Fischer, Harry. *Forthcoming.* Beyond participation and accountability: Theorizing representation in local democracy. *World Development.*

Fischer, Harry, and N. L. Narasimha Reddy. *Forthcoming.* Can more drought resistant crops lead to more climate secure livelihoods? Prospects and challenges of millet cultivation in Ananthapur, India. *World Development Perspectives.*

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Previous Research :

Pilot study to develop a research program on the socio-ecological effects of afforestation, Kangra District of Himachal Pradesh, India. Overseeing survey data collection, participatory mapping, and interviews on resources use and change across 20 villages. March 2016-present.

Postdoctoral research on public assistance, rural livelihoods, and agriculture in India with the Revitalizing Rainfed Agriculture Network. Helped to design and implement a large-scale data collection effort of 6000 households across study sites in 6 Indian states. January 2015-present.

Dissertation fieldwork on the local governance and natural resource management: Kangra District of Himachal Pradesh; including designing and coordinating a large data collection effort over 40 villages and 1600 households, complemented with extended qualitative fieldwork on local government January 2012 – August 2014.

Study to examine the institutional factors that aid in climate vulnerability reduction and adaptation in Mandi District, Himachal Pradesh, India: May-June 2010.

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PROFESSIONAL PREPARATION

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University of Illinois–Urbana-Champaign, Natural Resources & Environmental Sciences		PhD, 2006
Boğaziçi University	Industrial Engineering	MS, 2000
Boğaziçi University	Industrial Engineering	BS, 1997

ACADEMIC AND PROFESSIONAL APPOINTMENTS

2010 – Present *Research Assistant Professor*, Geography, Texas A&M University
Fall 2009 *Lecturer*, Forestry and Environmental Studies, Yale University
Summer 2006 *Intern*, Millennium Institute, Arlington VA
2000 – 2006 *Research Assistant*, Natural Res. & Environ. Sci., Unv. of Illinois–Urbana-Champaign
1997 – 2000 *Research and Teaching Assistant*, Industrial Engineering, Boğaziçi University

RESEARCH AND PROFESSIONAL ACTIVITIES:

Dr. Burak Güneralp is a Research Assistant Professor at Texas A&M University. He has over fifteen years of research experience on interactions between natural and human systems, including socio-economic and environmental problems of contemporary urbanization. His core analytical strengths are in geospatial analysis, including GIS and remote sensing applications, and systems analysis. He has expertise in land change analysis and modeling, systems modeling and simulation of socio-economic systems. He served as a contributing author for the chapter on Human Settlements, Infrastructure and Spatial Planning in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report.

MOST RELATED PUBLICATIONS

Saxena A, **B Güneralp**, R Bailis, G Yohe and C Oliver. 2016. Evaluating the resilience of forest dependent communities in Central India by combining the sustainable livelihoods framework and the cross scale resilience analysis. *Current Science* 110(7): 1195-1207.

Güneralp B, İ Güneralp, C Castillo and A Filippi. 2013. Land change in the Mission-Aransas coastal region, Texas: implications for coastal vulnerability and protected areas. *Sustainability* 5(10): 4247-4267.

Duer-Balkind, M, KR Jacobs, **B Güneralp** and X Basurto. 2013. Resilience, Social-Ecological Rules, and Environmental Variability in a Two-Species Artisanal Fishery. *Ecology and Society* 18(4): 50.

Xu C, **B Güneralp**, GZ Gertner and RM Scheller. 2010. Elasticity and loop analysis: tools for understanding forest landscape response to climatic change in spatial dynamic models. *Landscape Ecology* 25(6): 855-871.

Anderson, AB, GX Wang, SF Fang, GZ Gertner, **B Güneralp** and D Jones. 2005. Assessing and predicting changes in vegetation cover associated with military land use activities using field monitoring data at Fort Hood, Texas. *Journal of Terramechanics* 42(3–4): 207–229.

OTHER SIGNIFICANT PUBLICATIONS

Güneralp B, Seto KC. 2013. Futures of global urban expansion: uncertainties and implications for biodiversity conservation *Environmental Research Letters* 8: 014025.

Güneralp B, KC Seto and M Ramachandran. 2013. Evidence of urban land teleconnections and impacts on hinterlands. *Current Opinion in Environmental Sustainability* 5(5): 445-451.

Seto KC, **B Güneralp**, LR Hutyra. 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the United States of America* 109(40): 16083-16088.

Güneralp B and G Gertner. 2007. Feedback loop dominance analysis of two tree mortality models: relationship between structure and behavior. *Tree Physiology* 27: 269–280.

Güneralp B, G Gertner, G Mendoza and A Anderson. 2003. Spatial simulation and fuzzy threshold analyses for allocating restoration areas. *Transactions in GIS* 7(3): 325–343

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Professional Preparation

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M.A., Economics, Utah State University, Logan, Utah, 1989
M.S., Grassland Science, University of Natal, South Africa, 1985
B.S., Grassland Science (*cum laude*), University of Natal, South Africa, 1982

ACADEMIC AND PROFESSIONAL APPOINTMENTS

Sept 2010-present	Professor, Department of Ecosystem Science & Management, TAMU
Sept 2004-Aug 2008	Associate Professor, Department of Ecosystem Science & Management, TAMU
Jan 1998-Aug 2004	Assistant Professor, Department of Rangeland Ecology & Management, TAMU
Nov 1996-Dec 1997	Sales Manager/Assistant Product Line Manager, OI Corp, College Station, Texas
Sept 1995-Oct 1996	Assistant Project Manager, Pioneer Environmental Services, Logan, Utah
Aug 1994-Aug 1995	President, Vector Flow L.C., College Station, Texas
Dec 1992-Jul 1994	Research Associate, Department of Rangeland Ecology & Management, TAMU
Feb 1990-Nov 1991	Associate Research Fellow, World Wide Fund for Nature, Zimbabwe
Sept 1987-Dec 1989	Research/Teaching Assistant, Range Science Dept, Utah State Univ, Logan, Utah
July 1984-Dec 1985	Lecturer, Grassland Science Department, University of Natal, South Africa
Feb 1983-Jun 1984	Research Scientist, Department of Agriculture, South Africa
July 1978-Dec 1978	Wildlife Manager, Lone Star Ranch, Zimbabwe

SELECTED RELEVANT PUBLICATIONS

Stroman D.A. U.P. Kreuter. 2016. Landowner satisfaction with the Wetland Reserve Program in Texas: A Mixed Methods Analysis. Environmental Management, 57:97-108. DOI 10.1007/s00267-015-0596-8

Wonkka, C.L., W.E. Rogers, U.P. Kreuter. 2015. Legal barriers to effective ecosystem management: Exploring linkages between liability, regulations, and prescribed fire. Ecological Applications, 25(8):2382-2393

Stroman, D.A., U.P. Kreuter. 2015. Factors influencing land management practices on conservation easement protected landscapes. Society & Natural Resources, 28:8, 891-907

Stroman, D.A., U.P. Kreuter. 2014. Perpetual conservation easements and landowners: Evaluating easement knowledge, satisfaction and partner organization relationships. Journal of Environmental Management, 146:284-291

Sorice, M.G., U.P. Kreuter, B.P. Wilcox, W.E. Fox III. 2014. Changing landowners, changing ecosystem? Land ownership motivations as drivers of land management practices. Journal of Environmental Management, 133:144-152

Toledo, D., U.P. Kreuter, M.G. Sorice, C.A. Taylor, Jr. 2014. The role of prescribed burn associations in the application of prescribed fires in rangeland ecosystems. Journal of Environmental Management, 132:323-328

Toledo, D., M.G. Sorice, U.P. Kreuter. 2013. Social and ecological factors influencing attitudes towards the application of high intensity prescribed burns to restore fire adapted grassland ecosystems. Ecology and Society, 18(4):9

Twidwell, D., W.E. Rogers, S.D. Fuhlendorf, C.L. Wonkka, D.M. Engle, J.R. Weir, U.P. Kreuter, C.A. Taylor, Jr. 2013.The rising Great Plains fire campaign: Citizenry response to woody plant encroachment. Frontiers in Ecology and the Environment, 11 (Online Issue 1): e64–e71, doi:10.1890/130015

Van Liew, D., J.R. Conner, U.P. Kreuter, W.R. Teague. 2012. An economic assessment of prescribed extreme fire and alternative methods for managing invasive brush species in Texas. Open Agricultural Journal, 6:17-26

Kreuter, U.P., H.G. Harris, M.D. Matlock, R.E. Lacey, 2001. Change in ecosystem service values in the San Antonio area, Texas. *Ecological Economics*, 39(3):333-346.

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PROFESSIONAL PREPARATION

North Carolina State University	Forestry and Environmental Resources	Postdoc, 2014-2015
University of Illinois at Urbana-Champaign,	Geography and GIS	PhD, 2010-2014
Indira Gandhi National Forest Academy	Forestry	PG Diploma, 1999-2002
CSK HP Agricultural University	Soil Sciences	MSc, 1999
CSK HP Agricultural University	Agricultural Sciences	BSc, 1997

ACADEMIC AND PROFESSIONAL APPOINTMENTS

April 2015 –Present	*Conservator of Forests cum Project Director, HP Forest Ecosystems Climate Proofing Project, Dharamshala, India*
2014 – 2015	*Postdoctoral Research Scholar*, Forestry and Environmental Resources, North Carolina State University
2010 – 2014	*Research and Teaching Assistant*, University of Illinois at Urbana-Champaign
2002 – 2010	*Deputy Conservator of Forests, Govt. of Himachal Pradesh*
1999–2002	*Indian Forest Service Probationer, Ministry of Environment and Forests, Govt of India*

MOST RELATED PUBLICATIONS

Rana, P. and Chhatre, A. (2016): Rules and Exceptions: Regulatory challenges to Private Tree Felling in Northern India. *World Development,* 77: 143–153.

Jagger, P. and **Rana, P**. 2014. Designing Low-cost, Rigorous and Sustainable REDD+ Safeguard Information Systems. Using publicly available social and spatial data and impact evaluation methods to assess REDD+ social safeguards in Kalimantan, Indonesia REDD+ Safeguard Briefs.

Rana, P. and Sills, E. 2015: A methodological brief on evaluating the impact of forest management certification. submitted to CIFOR.

Chhatre, A., **Rana, P**. and Prasanna, S. 2011. Forest Cooperatives in India are a Model for Community Forestry. *Silviculture*. Summer 2011: 8-11.

Rana, P and Singh C.J. 2009. Co-management options for plantations development: a case study from district Sirmour of Himachal Pradesh. *Indian Forester*, 135 (9):1193-1201.

Rana, P. 2009. The Use and Management of Trees and Forests in Himachal Pradesh, India in the next 20 years. In Robin N. Leslie (ed.) *The Future of Forest in Asia and the Pacific: Outlook for 2020*. Bangkok: FAO Regional Office for Asia and the Pacific, 598-600.

OTHER SIGNIFICANT PUBLICATIONS

Rana, P. and Rana, R. 2007. Dominant Medicinal Plant Species in Pangi valley: Study of their Ecological Profile, Trends in Trade and Contribution to State Royalty. *ENVIS Forestry Bulletin*, 7(2): 81-86.

Singh, C.J., Sultan, Z., Gusain, M.S., Kumar, Anuj and **Rana, P. S**. 2007. Demand and Supply of Medicinal Plants in Himachal Pradesh: A Situational Review. *ENVIS Forestry Bulletin*, 7(2): 87-93.

CURRICULUM VITAE

Claudia Rodriguez Solorzano

PERSONAL AND BUSINESS INFORMATION

Department of Ecosystem Science & Management
Texas A&M University
HFSB 311
College Station, TX 77843

T: (979) 862-1058
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http://claudiarodriguezsolorzano.weebly.com/

PROFESSIONAL PREPARATION

Dartmouth College	Environmental Studies	Postdoc, 2013-2016
University of California, San Diego	Center for US-Mexican Studies	Postdoc, 2011-2012
University of Michigan	Natural Resources & Environment	PhD, 2011
University of Chicago	Public Policy	MS, 2001
Instituto Tecnológico Autónomo de México (ITAM)	Economics	BA, 2001

ACADEMIC AND PROFESSIONAL APPOINTMENTS

2013 – Present *Visiting Research Scientist*, Ecosystem Science & Management, Texas A&M University
2013-Present *Research Associate,* Environmental Studies, Dartmouth College & NSF Science, Engineering, and Education for Sustainability fellow.
2012-13 *Visiting Scholar,* Environmental Studies, Dartmouth College & Anthropological Center for Training & Research on Global Environmental Change, Indiana University.
2011-2012 *Postdoctoral fellow.* Center for US-Mexican Studies, UC San Diego
2010-2011 *Predoctoral visiting fellow,* Workshop in Political Theory & Policy Analysis, Indiana University, Bloomington
2001-2004 *Sub-director*, National Institute of Ecology, Mexico.
1998-1999 *Sub-director,* Federal Energy Ministry, Mexico.
1997-1998 *Advisor,* Mexico City Finance Ministry
1996-1997 *Researcher,* Mexico City Environmental Ministry

MOST RELATED PUBLICATIONS

Rodriguez-Solórzano, C. (In Press) "Connecting social adaptation to climate variability and change and land use change in internationally adjoining protected areas." *Conservation and Society*.

Rodriguez-Solórzano, C. (2014). "Unintended outcomes of farmers adaptation to climate variability: deforestation and conservation in Calakmul and Maya biosphere reserves." *Ecology and Society* 19(2).

Nelson, F., E. Collins, A. Frechette, C. Koenig, M. Jones-Yellin, B. Morgan, G. Ramsay, G. Rao, C. Rodriguez, Z. Tulu, C. Watkins, J. Zinda (2008). "Preservation or degradation? Communal Management and Ecological Change in a Southeast Michigan Forest." *Biodiversity and Conservation* 17(11): 2757-2772.

Rodríguez-Solórzano, C., (2003) Mexican Environmental Decentralization, in: Claudia, Rodríguez-Solórzano (Ed.), *Decentralization in Mexico: Reflections and Experiences to Guide Environmental Policy*. National Institute of Ecology, Mexico City, Mexico.

Rodriguez-Solórzano, C., (Ed.), (2003) *Decentralization in Mexico: Reflections and Experiences to Guide Environmental Policy*, National Institute of Ecology, Mexico City, Mexico.

Table of Personnel and Work Effort

Title	Name	Work commitment funded by NASA (Months)	Work commitment not funded by NASA (Months)	Institution
Principal Investigator/Assistant professor	Forrest Fleischman	1	1	Texas A&M Agrilife
Co-Investigator/professor	Urs Kreuter	1/4	0	Texas A&M Agrilife
Co-Investigator/visiting research scientist	Claudia Rodriguez Solorzano	1	1	Texas A&M Agrilife
Postdoctoral associate	TBN	12	0	Texas A&M Agrilife
Co-Investigator/ Research Assistant professor	Burak Güneralp	2	0	Texas A&M
Co-investigator/ Associate Professor	Anthony M. Fillippi	1/2	0	Texas A&M
Co-Investigator/ Associate Professor¬¬¬	Eric Coleman	1	0	Florida State University
Co-investigator/ Associate Professor	Ashwini Chhatre		1	Indian School of Business
Co-investigator/ Postdoctoral associate	Harry S. Fischer		1	Indian School of Business
Co-Investigator/ Conservator of Forests	Pushpendra Rana		1	Himachal Pradesh Forest Department

Current and Pending support

Information is provided for the PI and all co-investigators responsible for 10% or more of the project.

Forrest Fleischman

1. Funding Received
    a. Title of Project: "Information flows about drought adaptation planning among Texas Agrilife Extension County Agents"
    b. Name of PI on award: Forrest Fleischman and David Briske
    c. Program Name & contact: Funded by the Texas A&M Program to Enhance Scholarly & Creative, Texas A&M Division of Research, James Izat, 979-862-1860 jizat@tamu.edu
    d. Performance Period: May 1 2016- April 31 2017
    e. Total amount received: $18,000
    f. Commitment per year: 1 month
2. Funding anticipated
    a. Title of Project: "Fighting Wildfire with Prescribed Burning in the Southern Great Plains: Social and Regulatory Barriers and Facilitators"
    b. Name of PI on award: Urs Kreuter (Fleischman is co-PI)
    c. Program name & contact: Joint Fire Science Program, John Hall, Program Director, 208-387-5945, j2hall@blm.gov
    d. Performance Period: September 1 2016- August 31, 2019 (award made, pending funding)
    e. Total amount received: $359,248, $50,000 to Fleischman
    f. Commitment per year: 1 month
3. Funding proposal submitted
    a. Title of Project: "Understanding how decision-making processes affect the allocation of disaster relief funds to coastal communities in the Gulf of Mexico"
    b. Name of PI on award: Forrest Fleischman
    c. Program name & contact: National Academy of Sciences Gulf Research Program, Chris Elfring, Executive Direcor, 202.334.2000, gulfprogram@nas.edu
    d. Performance Period: September 1 2016 – August 31, 2018 (pending review of applications)
    e. Total amount applied for: $216,202 ($182,031 to Fleischman)
    f. Commitment per year: 1 month
4. Application in preparation
    a. Title of Project: Texas-Mexico Transboundary Water Governance
    b. Name of PI on award: Kent Portney (Fleischman co-PI)
    c. Program name & contact: Program on International Water Cooperation, US State Department. Ms. Kathryn Pharr at PharrK@state.gov
    d. Performance Period: September 1 2016 – February 28 2018
    e. Total amount applied for: $300,000 ($25,000 to Fleischman)
    f. Commitment per year: 2 weeks
5. Application in preparation
    a. Title of Project: Valuing Urban Forest Ecosystem Services among disadvantaged groups to improve forest access and benefits in underserved communities

   b. Name of PI on award: Omkar Joshi (Fleischman co-PI)
   c. Program name & contact: 2017 U.S. Forest Service National Urban and Community Forestry Challenge Cost-Share Grant Program. Nancy Stremple, 202-309-9873
   d. Performance Period: September 1, 2016-August 31, 2017
   e. Total amount applied for: $300,000 ($100,000 to Fleischman)
   f. Comittment per year: 2 weeks
6. Application in preparation:
   a. Title of Project: The Southern Great Plains Savanna LTER
   b. Name of PI on award: Bradford Wilcox (Fleischman collaborator)
   c. Program name & contact: National Science Foundation Long-term Ecological Research Program, Sarah Twombly stwombly@nsf.gov, (703) 292-8133
   d. Performance Period: September 2017-August 2022
   e. Total amount applied for: $5,000,000 ($25,000 to Fleischman)
   f. Comittment per year: 1 week

CURRENT AND PENDING SUPPORT

Eric Andrew Coleman

CURRENT SUPPORT

Parker, R., Coleman, E., & Manyindo, J. (2015–2017). *TW8R2/1015 An Impact Assessment of Stakeholder Engagement Interventions in Ugandan Oil Extractives*. Funded by International Initiative for Impact Evaluation, Inc. (3ie). Total award $530,615.

- Performance Period 2015-2017.
- Total Award to co-PI Coleman: $58,036
- Commitment for 1 month of summer salary in each year: 2015, 2016, 2017

Coleman, E. (2016—2017) *Developing Scholar Award.* Funded by Florida State University. Total award: $22,500.

- Performance Period 2016-2017.
- No commitment for time, the award is flexible for ongoing research.

PENDING SUPPORT

de Oliveira, A. C. M., Coleman, E., & Jacobson, S. (2016). *Seventh Biennial Conference on Social Dilemmas.* Submitted to National Science Foundation. Total award $38,931.

- Performance Period 2016-2017.
- No commitment for time, the award is to organize and hold a conference.

Burak Güneralp

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Güneralp, Burak

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Synthesis of LCLUC studies on Urbanization: State of the Art, Gaps in Knowledge, and New Directions for Remote Sensing Science

Source of Support: NASA
Total Award Amount: $643,304 Total Award Period Covered: May 1, 2015 - April 30, 2018
Location of Project: Texas A&M University
Person-Months Per Year Committed to the Cal: 3.0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Bidirectional Reflectance Distribution Function Effect on Arsenic and Water-Stress Reduction in Rice

Source of Support: Ocean Optics
Total Award Amount: $10,000 Total Award Period Covered: September 1, 2013 – August 31, 2016
Location of Project: Texas A&M University
Person-Months Per Year Committed to the Cal: 0.2 Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Water Resilience and Food Security under Land Cover/Land Use Change in India

Source of Support: NASA
Total Award Amount: $741,677 Total Award Period Covered: May 1, 2017 – April 30, 2020
Location of Project: Texas A&M University
Person-Months Per Year Committed to the Cal: 3.0 Acad: Sumr:

Claudia Rodriguez Solorzano
CURRENT AND PENDING SUPPORT

Rodriguez-Solorzano, C. (PI, 2013-2016). *Understanding Farmers' Valuation of Environmental Services and Forest Sustainability: Governance and Institutions in the Selva Zoque, México.* Postdoctoral fellowship from Science, Engineering, and Education for Sustainability Program. Funded by National Science Foundation. Total award 524,880, all to the PI. 100% time commitment to this project, which ends August 31, 2016 (before the anticipated start date of this grant)

Statements of Commitment and Letters of Support

Statement of Commitment from Indian School of Business (Chhatre and Fischer)

ISB

Date: May 26, 2016

Dear NASA reviewers,

I am writing to endorse the proposal: "Impacts of artificial afforestation on the provision of ecosystem services to rural communities in India, A Step-2 proposal in response to NASA solicitation NNH15ZDA001N-LCLUC", led by Dr. Forrest Fleischman. I have read this proposal and agree to take part in the project, as described in the proposal document. I understand that I will not receive any funding from NASA as a result of my participation in this project. I will use existing resources available to me including existing grants for work on forests and livelihoods, as well as deploying personnel from my research group towards assisting this project. In particular, Harry Fischer, a Post-doctoral Fellow at ISB and working in my research group has been actively working with Dr. Fleischman in developing this proposal and will continue to spend substantial time on this research.

Sincerely

Ashwini Chhatre

Senior Research Fellow and Visiting Professor

INDIAN SCHOOL OF BUSINESS
Gachibowli, Hyderabad 500 032, India. Tel : +91 40 2300 7000
www.isb.edu

Statement of Commitment from Dr. Pushpendra Rana, IFS

LETTER OF ENDORSEMENT

I have been posted as Project Director, HP Forest Ecosystem Climate Proofing Project at Dharamshala. I am supervising the project activities including the establishment of baseline survey (including criteria and indicators and their assessment in the context of afforestation in degraded landscapes) for the Climate Proofing project and in this regard, endorsing the proposal "Impacts of artificial afforestation on the provision of ecosystem services to rural communities in India, A Step-2 proposal in response to NASA solicitation NNH15ZDA001N-LCLUC led by Dr. Forrest Fleischman. I have read the proposal and understand that I will not receive any funding from NASA as a result of my participation in this project. I will use the existing resources to support my participation mainly in my off-office capacity and duration to learn from the proposal and include the learning in the execution of the Climate Proofing Project.

My office address is given below:

Dr. Pushpendra Rana, IFS
Project Director
Himachal Pradesh Forest Ecosystems Climate Proofing Project
Forest Complex, Near Judicial Courts
Dharamshala, Himachal Pradesh, India
176215

Project Director
H.P Forest Ecosystem
Climate Proofing (Kfw)
Project Dharamshala

HP Forest Ecosystems Climate Proofing Project
Dharamshala, Himachal Pradesh, India 176215
Phone No. 01892-223000

Budget Justification: Narrative and Details

Budget: Texas A&M Agrilife Research

Cumulative Budget Request (all figures in $)							
Category							-
A. Sr Personnel				**Year 1**	**Year 2**	**Year 3**	**TOTAL**
Name	**Project Role**						
Forrest Fleischman	Principal Investigator		Person Months	1.00	1.00	1.00	
			Salary	8,165	8,410	8,662	25,237
			Fringe	1,453	1,497	1,542	4,492
			Insurance	695	695	695	2,085
			Total Fringe	2,148	2,192	2,237	6,577
Urs Kreuter	Co-I		Person Months	0.25	0.25	0.25	
			Salary	2,713	2,794	2,878	8,385
			Fringe	483	497	512	1,492
			Insurance	173	173	173	519
			Total Fringe	656	670	685	2,011
Claudia Rodriguez Solorzano	Co-I		Person Months	1.00	1.00	1.00	
			Salary	5,577	5,744	5,917	17,238
			Fringe	993	1,022	1,053	3,068
			Insurance	695	695	695	2,085
			Total Fringe	1,688	1,717	1,748	5,153
Subtotal Salaries Senior Personnel				16,455	16,948	17,457	50,860
Subtotal Benefits Senior Personnel				4,492	4,579	4,670	13,741
Subtotal Senior Personnel				20,947	21,527	22,127	64,601
B. Other Personnel			-				
Name	**Project Role**			**Year 1**	**Year 2**	**Year 3**	**TOTAL**
TBN	Post Doc		Person Months	12.00	12.00	12.00	-
			# of Persons	1	1	1	-
			Salary	41,811	43,065	44,357	129,233
			Fringe	7,442	7,666	7,896	23,004
			Insurance	8,340	8,340	8,340	25,020
			Total Fringe	15,782	16,006	16,236	48,024
Subtotal Salaries Other Personnel				41,811	43,065	44,357	129,233
Subtotal Benefits Other Personnel				15,782	16,006	16,236	48,024
Subtotal Other Personnel				57,593	59,071	60,593	177,257

Total Salaries				**58,266**	**60,013**	**61,814**	**180,093**
Total Benefits				**20,274**	**20,585**	**20,906**	**61,765**
	Total Personnel Costs			**78,540**	**80,598**	**82,720**	**241,858**
DIRECT COSTS							
Travel: Domestic	(travel costs broken down in justification)						
	Travel: LCLUC meeting			1,000	1,000	1,000	3,000
	Total Domestic Travel			**1,000**	**1,000**	**1,000**	**3,000**
Travel: Foreign							
	Travel to India			13,300	11,000	3,750	28,050
	Total Foreign Travel			**13,300**	**11,000**	**3,750**	**28,050**
Materials & Supplies							
	Tablets for field data collection			1,200	-	-	1,200
	Total Supplies			**1,200**	**-**	**-**	**1,200**
Other Costs							
	Field research expenses in India			30,000	50,000		80,000
	Total Other Costs			**30,000**	**50,000**	**-**	**80,000**
SubRecipient Costs							
	Florida State University			27,041	23,147	28,400	78,587
	TAMU			44,945	42,625	45,867	133,437
	Total SubRecipient Costs			**71,986**	**65,772**	**74,267**	**212,024**
Modified Total Direct Costs (MTDC)				**149,040**	**142,598**	**87,470**	**379,108**
Total Direct Costs (TDC)				**196,026**	**208,370**	**161,737**	**566,132**
INDIRECT COSTS	Rate		**Base**				
	48.5%		MTDC	72,284	69,160	42,423	183,867
TOTAL REQUEST FROM SPONSOR (TRS)				**268,310**	**277,530**	**204,160**	**749,999**

Budget Narrative – Texas A&M Agrilife Research

Type of award anticipated

We anticipate receiving a grant.

Cost Estimates

Senior Personnel: $50,860

The following personnel are included in the grant.

The PI, Forrest Fleischman, is budgeted at a rate of 1 person-month per year for the duration of the project. Monthly salary is budgeted as $8,165 for the first year, with a 3% raise per year, and 17.8% fringe + 695/month in insurance. The PI will be responsible for project coordination and direction, research design, and analysis, and will need to travel to the field sites annually to supervise field work.

Co-Investigator Urs Kreuter, is budgeted at a rate of 0.25 person month per year for the duration of the project. Monthly salary is budgeted as $2,713 for the first year, with a 3% raise per year, and 17.8% fringe + 695/month in insurance. Dr. Kreuter will be responsible for economic analysis of livelihood data.

Co-Investigator Claudia Rodriguez Solorzano is budgeted at a rate of 1 person-month per year for the duration of the project. Monthly salary is budgeted as $5,577 for the first year, with a 3% raise per year, and 17.8% fringe + 695/month in insurance. Dr. Rodriguez Solorzano will be responsible for design and implementation of data collection and analysis for household and community level livelihood surveys.

Other Personnel: $ 129,233

Funding is provided for 1 full-time postdoctoral associate for the duration of the grant. The postdoctoral position's salary will begin at $41,473, with a 3% raise per year, fringe of 17.8%, and insurance of 695/month. The postdoctoral position will be responsible for coordinating and supervising field data collection for both social surveys and spatial ground-truthing, as well as assisting with remote sensing and survey data analysis.

Fringe Benefits: $61,121
Senior Personnel: $13,741
Other Personnel: $ 48,024

Fringe benefits are calculated on Texas A&M AgriLife Research approved rates.

Travel: Domestic: $3,000

Funding is provided for 1 member of the project team to travel to one LCLUC Science Team Meeting for each of the three years of the project. Domestic round-trip airfare from College Station or Houston airport is estimated at $500 to location of domestic meeting (typically near Washington DC). Room and board is estimated at $250/night for 2 nights – thus $1000 per year

Travel: Foreign: $ 28,050

Due to the nature of the work, we anticipate frequent travel between India and the US. Estimates based on current airfares indicate that round trip airfares from Houston to Delhi will cost $1300/person/flight on US flag carriers. Domestic round-trip flights from Delhi to the field sites (Dharamsala-Kangra Gaggal Airport) cost approximately $100. Room & Board is set at $100/day for days spent in Delhi or other major cities, $50/day for short-term stays in Kangra district, and $30 for longer-term (great than 1 month) stays in Kangra district (because for longer term stays it will be possible to rent a room rather than stay in a hotel). When necessary, hiring a car for one day to visit field sites is estimated to cost $20. While these rates are substantially lower than GSA per diems, they are based on our extensive experience of the actual day-to-day

cost of traveling and working in this region.
Funding is provided as follows:

1. During year 1, all four members of the project team from Texas A&M Agrilife (i.e. Fleischman, Kreuter, Rodriguez Solorzano, and the postdoc), along with Güneralp from Texas A&M, and Coleman from Florida State (budgeted separately), will travel to the field site to begin field surveys, insure that field protocols are well designed, and supervise the hiring and training of the field team. This will be done during July and August 2017, with the final dates to be determined. Kreuter will stay for 2 weeks, Fleischman & Rodriguez Solorzano for 1 month, and the postdoc for 3 months. Costs will be as follows:
    - **a.** Round-trip airfare from Houston to Delhi for 4 people: 4x1300=$5200
    - **b.** Round-trip airfare from Delhi to Kangra District for 4 people: 4x100=$400
    - **c.** 2 nights stay in Delhi for 4 people (to make connections from international to domestic flights and to meet with key stakeholders in Delhi): 2*4*100 = $800
    - **d.** 14 days stay in Kangra for Kreuter: 50*14= $700
    - **e.** 30 days stay in Kangra for Fleischman & Rodriguez: 50*30*2 = 3000
    - **f.** 90 days stay in Kangra for postdoc: 90*30 = 2700
    - **g.** 25 days car hire for reaching field sites: 25*20 = 500

Total for year 1 = 5200+400+800+700+3000+2700+500= 13,300

2. During year 2, a smaller team will travel to the field sites to supervise data collection. Fleischman & Rodriguez Solorzano will spend 1 month in the field, while the postdoc will spend 3 months in the field.
    - **a.** Round-trip airfare from Houston to Delhi for 3 people: 3x1300=$3900
    - **b.** Round-trip airfare from Delhi to Kangra District for 3 people: 3x100=$300
    - **c.** 2 nights stay in Delhi for 3 people (to make connections from international to domestic flights and to meet with key stakeholders in Delhi): 3*2*100 = $600
    - **d.** 20 days stay in Kangra for Fleischman & Rodriguez: 50*20*2 = 2000
    - **e.** 90 days stay in Kangra for postdoc: 90*30 = 2700
    - **f.** 25 days car hire for reaching field sites: 45*20 = 500

Total for year 2 = 3900+300+600+3000+2700+500 = 11,000

3. During year 3, no field work will be conducted. Fleischman will travel to the field site, as well as the cities of Shimla (capital of Himachal Pradesh), Delhi, Hyderabad, and Bangalore to present results of the research.
    - **a.** Round-trip airfare from Houston to Delhi for 1 person:1300
    - **b.** Round-trip airfare from Delhi to Kangra District for 1 person: 100
    - **c.** Additional allowance for travel to other cities in India (3 domestic flights, estimated at $200/person): 3x200= $600
    - **d.** 1 week stay in Kangra/Shimla = 50x7= 350
    - **e.** 2 weeks stay in major cities for other events/meetings to present research = 14**100=$1400

Total for year 3 = 1300+ 100 +600+350+1400 = 3750

Materials and Supplies: $1200

We will purchase android tablets for recording survey responses in the field for each of the 6 teams of survey enumerators. Cost is estimated at $200/tablet (based on the cost of an Asus Zen 3 tablet on Amazon.com), for a total cost of $1200. All will be purchased during the first year.

Other Costs: $80,000

We will hire a team of local field assistants in Kangra, working with local people who have previously worked as research assistants for our Indian partners.

Village level surveys will be conducted by teams of two locally hired field assistants, and will begin in the 6th month of the project, continuing until the end of the second year. Our preliminary field work in April 2016 indicates that a team of two can conduct 30 household surveys, as well as key informant surveys, in 2 weeks, with an additional week allowed for ground truthing. Thus, each team can complete both ground truthing and survey field work in 3 villages in 2 months. 6 teams will be able to complete surveys in 144 villages, 4 more than needed, in 16 months (months 6-22 of the project), with 2 extra months remaining in the second year which can be used, if necessary, to make up any unexpected delays in field work.
Field assistants will be paid a salary of 16,000 Indian rupees/month, plus 4,000 for transportation costs. 2 full-time field coordinators will be hired at a rate of rs 30,000/month, plus 5,000 for transportation. These wage rates are based on competitive wage rates in Kangra district that we discovered during preliminary field research in April/May 2016. The proposed field coordinators worked for us to collect preliminary data during this period. Thus the monthly cost of the field crew will be rs. 16,000x12+4000x12+30,000x2+5000x2 = rs. 310,000. At today's exchange rate this is $4,600, however we are budgeting $5,000 per month to account for potential exchange rate fluctuations and costs of international money transfers.

The field team will work for 6 months during year 1 (5000x6= $30,000) and 10 months during year 2 (5,000x10= 50,000).

Sub-recipient costs: $212,024
Texas A&M: $133,437
Florida State University: $78,587
Texas A&M and Florida State University. Burak Güneralp will lead the Texas A&M subaward, with the assistance of Anthony Fillippi, and both will focus on remote sensing analysis. Eric Coleman will lead the Florida State award, and will assist the PI with research design and data analysis. Separate budget justifications are provided for these contributions.

Indirect Cost: $ 183,867
The indirect cost is calculated at Texas A&M's federally negotiated rate of _48.5___% MTDC exempting graduate student tuition and fees, equipment over $5,000 and subaward costs after the first $25,000 of each subaward

Subaward to Texas A&M

Budget

Category	**Monthly**	**% Effort**	**Monthly Equivalence**						
	Salary	**Requested**	**Cal Mo**	**Aca Mo**	**Sum Mo**	**Year 1**	**Year 2**	**Year 3**	**TOTAL**
A. Sr Personnel									
PI: Burak Güneralp	$ 6,890.00	17.00 %	2.0	1.5	0.5	14,477	14,912	15,359	44,748
Fringe Benefits		17.00 %	2.0	1.5	0.5	3,995	4,072	4,152	12,219
		17.00 %	2.0	1.5	0.5				
Co-I: Anthony M. Filippi	$ 8,129.00	3%	0.3	0.2	0.1	2,512	2,587	2,665	7,764
Fringe Benefits		3%	0.3	0.2	0.1	656	669	683	2,008
		3%	0.3	0.2	0.1				
Subtotal Salaries Senior Personnel						16,989	17,499	18,024	52,512
Subtotal Benefits Senior Personnel						4,651	4,741	4,835	14,227
Subtotal Senior Personnel						21,640	22,240	22,859	66,739
B. Other Personnel			**Hours**	**Wage**	**Students**	**Year 1**	**Year 2**	**Year 3**	**TOTAL**
Graduate Student Labor			300	$ 19	1	5,700	5,871	6,047	17,618
Fringe Benefits						576	593	611	1,780
Subtotal Salaries Other Personnel						5,700	5,871	6,047	17,618
Subtotal Benefits Other Personnel						576	593	611	1,780
Subtotal Other Personnel						6,276	6,464	6,658	19,398
Total Salaries						**22,689**	**23,370**	**24,071**	**70,130**
Total Benefits						**5,227**	**5,334**	**5,446**	**16,007**
Total Personnel Costs						**27,916**	**28,704**	**29,517**	**86,137**

DIRECT COSTS									
Travel: Domestic	Item	$Amount	# of People	# of Days	# of Trips				
	Per diem	$ 74	1	5	1			370	370
	Lodging	$ 100	1	5	1			500	500
AGU Fall Meeting	Transportation	$ 500	1		1			500	500
	Rental Car	$ -		5	1	-	-	-	-
	Mileage	$ -			1	-	-	-	-
	Other	$ -				-	-	-	-
	Total Trip					-	-	*1,370*	*1,370*
	Total Domestic Travel					-	-	*1,370*	*1,370*
Travel: Foreign	Item	$Amount	# of People	# of Days	# of Trips				
City:	Per diem	$ 50	1	19	1	950			950
	Lodging		1	19	1	-			-
Field work	Transportation	$ 1,400	1		1	1,400			1,400
	Rental Car	$ -			1	-	-	-	-
	Mileage	$ -			1	-	-	-	-
Note: put conference registration	Other	$ -				-	-	-	-
under Other Direct Costs	*Total Trip*					*2,350*	-	-	*2,350*
	Total Foreign Travel					*2,350*	-	-	*2,350*
Modified Total Direct Costs (MTDC)						***30,266***	***28,704***	***30,887***	***89,857***
EXEMPT COSTS									
Total Direct Costs (TDC)						***30,266***	***28,704***	***30,887***	***89,857***
INDIRECT COSTS									
Indirect Costs			**48.5%**	of	**MTDC**	14,679	13,921	14,980	43,580
TOTAL PROJECT COSTS (TPC)						**44,945**	**42,625**	**45,867**	**133,437**

Budget narrative:

Budget Justification

PERSONNEL **$70,130**

PI-Burak Güneralp – is requesting 2.04 month of salary in each of the three years at the current monthly salary of $7,223. Dr. Güneralp is on "soft-money" position. He will lead TAMU and will be responsible for conducting the field work to collect in situ ground-truthing data, conducting and coordinating remote sensing analysis.

CO-PI- Anthony M. Filippi – is requesting .30 month of salary in each of the three years at the current monthly salary of $8,129. He will be assisting Dr. Güneralp in novel applications of spectral unmixing algorithms for Landsat data in remote sensing analysis.

Graduate Student- will assist in data processing for remote sensing analysis and in different project components. Student will commit to 300 hours on duration of project.

Salaries and wages are increased by 3% each year, to allow for a cost-of-living adjustment. Fringe benefits are calculated at the TAMU rates of 17.8% for faculty (PI and Co-PI) and 10.1% for graduate students.

Fringe Benefits **$16,007**

Insurance benefits are calculated at the Texas A&M rate of $695 per month for faculty (PI, Co-PI) and $360 per month for graduate students.

Travel **$3,720**

Domestic:

$1,370 is requested for institutional PI Güneralp for travel to the Annual Fall Meeting of the American Geophysical Union (AGU), which will be held in December in San Francisco in 2019. The meeting is an important scientific venue to disseminate the findings from the proposed research to our intended audiences. The meeting brings top academics and practitioners who study geophysical systems and global environmental change across a wide spectrum together. The costs of attending have been derived by a cost-accounting approach based on actual quotes.

Foreign:

$2,350 is requested for institutional PI Güneralp for travel to study sites in India in year 1 to conduct field work. *In situ* data will constitute reference ground-truthing data for characterizing land cover and land use at the study sites and composition of vegetation in and around the plantation sties. Estimates based on current airfares indicate that round trip airfares from Houston to Delhi will cost $1,300/person/flight on US flag carriers. Domestic round-trip flights from Delhi to the field sites (Dharamsala-Kangra Gaggal Airport) cost approximately $100. Room & Board is set at $100/day for days spent in Delhi or other major cities, $50/day for short-term stays in Kangra district. While these rates are substantially lower than GSA per diems, they are based on our extensive experience of the actual day-to-day cost of traveling and working in this region.

Institutional PI Güneralp will share the car to be hired by PI Fleischman to visit field sites and collect ground-truthing data. He will be assisted, as needed, by the local field assistants and the postdoc who are on PI Fleischman's budget.

Funding is provided as follows:

1. During year 1, institutional PI Güneralp, along with all four members of the project team from Texas A&M Agrilife (i.e. Fleischman, Kreuter, Rodriguez Solorzano, and the postdoc), and Coleman from Florida State, will travel to the field site to begin field surveys and collect ground-truthing data. This will be done during July and August 2017, with the final dates to be determined. Güneralp will stay for 15 days. Costs will be as follows:
    a. Round-trip airfare from Houston to Delhi for 1 person: 1x1,300=$1,300
    b. Round-trip airfare from Delhi to Kangra District for 1 person: 1x100=$100
    c. 2 nights stay in Delhi for 1 person (to make connections from international to domestic flights and to meet with key stakeholders in Delhi): 2*1*100 = $200

Total for year 1 = $1,300+$100+$200+$750= $2,350

Indirect Costs **$44,041**

Indirect costs are calculated at the negotiated rate of 48.5% of modified total direct costs, which excludes equipment for use on grants and contracts.

Subaward to Florida State University:

Budget

Cumulative Budget Request							
Category							
A. Sr Personnel				**Year 1**	**Year 2**	**Year 3**	**TOTAL**
Name	**Project Role**						
Eric A. Coleman	Co-PI		Person Months	1.00	1.00	1.00	
			Salary	$ 12,638	$ 13,012	$ 13,402	$ 39,052
			Fringe	$ 2,152	$ 2,216	$ 2,282	$ 6,650
			Insurance	$ -	$ -	$ -	$ -
			Total Fringe	$ 2,152	$ 2,216	$ 2,282	$ 6,650
Subtotal Salaries Senior Personnel				$ 12,638	$ 13,012	$ 13,402	$ 39,052
Subtotal Benefits Senior Personnel				$ 2,152	$ 2,216	$ 2,282	$ 6,650
Subtotal Senior Personnel				$ 14,790	$ 15,228	$ 15,684	$ 45,702
				Year 1	**Year 2**	**Year 3**	**TOTAL**
Total Salaries				**$ 12,638**	**$ 13,012**	**$ 13,402**	$ 39,052
Total Benefits				**$ 2,152**	**$ 2,216**	**$ 2,282**	$ 6,650
	Total Personnel Costs			**$ 14,790**	**$ 15,228**	**$ 15,684**	**$ 45,702**
Travel: Foreign							
	Travel to India			$ 3,000		$ 3,000	$ 6,000
	Total Foreign Travel			**$ 3,000**	**$ -**	**$ 3,000**	**$ 6,000**
INDIRECT COSTS		**Rate**					
		52.0%	**Modified Direct**	**$ 9,250.80**	**$ 7,918.56**	**$ 9,715.68**	**$ 26,885**
TOTAL REQUEST FROM SPONSOR (TRS)				**$ 27,041**	**$ 23,147**	**$ 28,400**	**$ 78,587**

Budget Narrative

There are two types of funding for this proposal: senior personnel costs and foreign travel. I have budgeted one month of summer salary for each of the three years of the project.

Personnel

During the first year, summer 2017, I will spend time designing the household survey instrument and finalizing the sampling strategy. In summer 2018 I will help coordinate and clean the household survey data and begin data analysis. Finally, during summer 2019 I will finalize the data analysis, prepare manuscripts for journal articles and for stakeholder dissemination.

Foreign Travel

I have also budgeted foreign travel costs to India for 2017 and 2019. The 2017 trip will be used to train enumerators to use the household survey instrument. The 2019 trip will be used to disseminate the final research findings among interested stakeholders. For each trip I have budgeted roundtrip airfare to Delhi (approximately $1500 round trip from Tallahassee, FL), domestic air travel within India ($100), accommodation for two nights in Dehli (100 x 2 = $200), and $120 per diem for 10 days (= $1200). Thus, the total requested amount is $3000 for each trip

Facilities and equipment

The Departments of Geography and Ecosystem Science & Management, in particular, and Texas A&M University (TAMU), in general, have a number clusters –including a supercomputing facility (see below)– to accommodate different computational needs.

The Department of Ecosystem Science & Management is located on TAMU's main campus in College Station, and is a part of the College of Agriculture and Life Sciences, as well as Texas Agrilife Research and Extension agencies. The department has an advanced geospatial analysis laboratory, however for the purposes of this grant, we will rely on the capabilities of the Geography department, described below. The department provides office space and computing facilities for the PI, Fleischman, as well as co-PIs Kreuter and Rodriguez Solorzano, and will provide the same for the postdoctoral associate funded by this project.

The Department of Geography is located on TAMU's main campus in College Station, TX and is part of the College of Geosciences, one of the largest college research programs in the Texas A&M System. The Department's advanced geospatial analysis laboratory houses a mixture of UNIX, Linux, and Windows workstations and a multi-terabyte storage capacity for handling large-volume data sets. Geography Department houses a complete suite of HP printers and scanners, including large-format printers and scanners for high-quality map production.

TAMU Geography Geospatial Analysis Laboratory
The lab currently includes the following assets:
Instrumentation/Hardware: **(1)** Windows and Linux workstations, regularly updated; **(2)** Analytical Spectral Devices, Inc. (ASD) (Boulder, CO) FieldSpec Pro VNIR spectroradiometer (for above-surface spectral upwelling radiance $L_u(\lambda)$ or water-leaving radiance $L_w(\lambda)$ measurements and derived spectral remote-sensing reflectance $R_{rs}(\lambda)$ for all materials); includes VNIR underwater fiberoptic jumper cable, 5° FOV underwater lens, underwater cosine receptor for underwater/subsurface downwelling and upwelling irradiance, $E_{d-}(\lambda)$ and $E_{u-}(\lambda)$, respectively, and a variety of other attachments/accessories. The ASD spectrometer is available for obtaining spectral measurements of soil, vegetation, and other materials that can be used for linear and nonlinear spectral mixing studies. Filippi also has a 14.5 Volt 50-Watt lamp that is tripod-mountable for indoor, laboratory-based diffuse reflectance measurements over the 350-2500-nm wavelength region; **(3)** Coulter Counter® Model ZM.
Software: **(1)** HydroLight-EcoLight (version 5) (Sequoia Scientific, Inc.) (Bellevue, WA) radiative transfer model; **(2)** Lahey/Fujitsu Fortran 95 Express -- LF95 Version 5.7; **(3)** ENVI/IDL remote-sensing digital image processing software; **(4)** ESRI ARC/INFO, ArcGIS 10.x geographic information system (GIS) software; **(5)** IDRISI RS/GIS software (Taiga); **(6)** ERDAS/IMAGINE Essentials and IMAGINE AutoSync; **(7)** MATLAB; **(8)** Atmospheric CORrection Now (ACORN 6) (ImSpec LLC) for atmospheric correction of remotely-sensed imagery; **(9)** River Tools, RIVIX, LLC (single-user, academic license); **(10)** Access to SAS, SPSS/PASW Statistics, S-PLUS, and SigmaPlot statistical software packages; **(11)** Graphics software (e.g., Voxler), among other software packages; **(12)** Digital image processing software, specifically developed for canopy cover analysis (e.g., Hemisfer, vers. 1.5.1, academically-registered; Gap Light Analyzer, vers. 2), as well as other software.

Other Equipment in the Department of Geography, College of Geosciences, and TAMU
The Department possesses a range of Global Positioning System (GPS)/Global Navigation Satellite System (GNSS) receivers and equipment, including, Trimble GeoExplorer® handheld receivers, Trimble Pro XR and XRS differential GPS (DGPS) receivers, TSC2 and TSCe controllers, and a base station transmitter. PIs have access to multiple total stations, both within the Department of Geography, College of Geosciences, and across the TAMU campus, as well as equipment for conducting vegetation field surveys (e.g., tape measures, calipers, etc.). The Department of Geography and the Environmental Geosciences/Studies Program each owns a Nikon D5000 Digital Camera, including a mounted GPS unit and hemispherical lenses that can be used in vegetation canopy data collection.

TAMU Center for Geospatial Science, Applications and Technology (GEOSAT)
Instrumentation/Hardware: **(1)** Spectral Evolution, Inc.© PSR-1100-F compact hyperspectral field spectroradiometer, with leaf clip and associated ILM-105 fiber optic illuminator and bifurcated cable.
Software: **(1)** Trimble eCognition Developer, Server, and Essentials, 25 licenses (mix of perpetual and annual time-based licenses, with on-going support); **(2)** ENVI/IDL remote-sensing digital image processing software.

TAMU Supercomputing Facility
The Supercomputing Facility provides technical expertise and high-performance hardware to expedite large-scale scientific computation for research and instruction, and is available to co-I Güneralp free of charge.

Major available resources include:
(1) Nehalem iDataplex cluster (EOS) to which the Department of Geography has priority access. EOS is a high-performance cluster that runs Linux on 324 nodes equipped with Nehalem, and 48 nodes with Westmere processors. The storage and compute nodes have 24 GB of DDR3 1333 MHz memory while the head nodes have 48 GB of DDR3 1066 MHz memory.
(2) IBM Cluster 1600 (Hydra) that runs AIX and that is composed of a 52-node 832-processor IBM Cluster 1600 system. Each node is a symmetric multi-processor system with 16 1.9 GHz Power5+ processors and a shared memory of 32 gigabytes.
(3) Several Linux workstations for pre- and post-processing needs.
(4) A disk based storage archive for backing up files that are produced or used on the clusters.

In addition, the Supercomputing Facility provides advance technical support as needed to research teams across campus and offers collaborations in research projects with a large computational component.