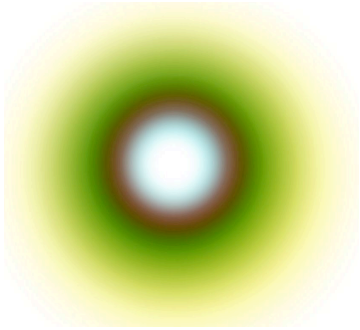

Living root bridge project

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Contents

Introduction

Living root bridge, Nongriat

Living root bridges are *Ficus elastica*-based suspension bridges within dense tropical rainforests of Meghalaya in the North-Eastern Indian Himalayas (25° 30' N and 91° 00' E). Ranging in span from 15 feet to 250 feet, these bridges are grown by indigenous Khasi tribes over a time period of 15 to 30 years, and last for several centuries. With 1) minimal material and maintenance cost, 2) no environmental damage, 3) carbon sequestration 4) exceptional robustness under extreme climatic conditions including storm surges and flash floods, 5) collective grass root involvement based on human-plant interaction across multiple generations, 6) remedial properties on surrounding soil, water and air, 7) support to other plant and animal systems, 8) keystone role of *Ficus* plant species in local ecology, and 9) superior performance as compared to conventional steel suspension bridges and bamboo bridges, living root bridges offer an extraordinary model for long-term socio-ecological resilience and sustainable community-based infrastructure solutions. However, despite these attributes, these bridges are being replaced by inappropriate solutions owing to increasing resource needs, changing bridge consciousness and the nexus of poverty, population explosion and environmental degradation.

Solution / Strategy

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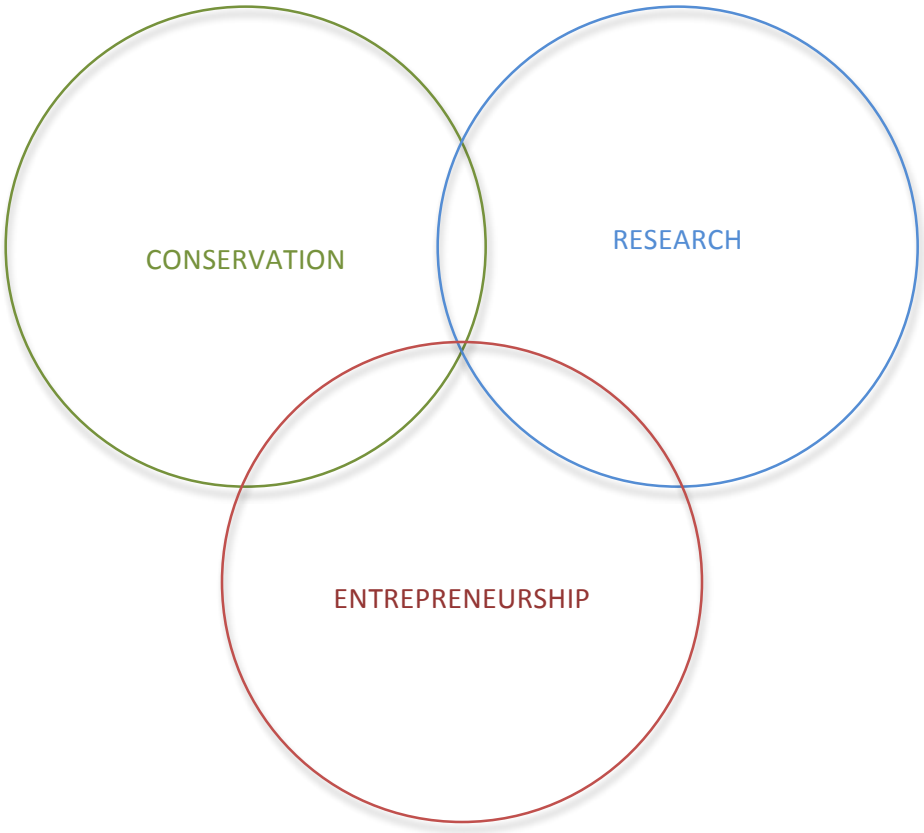
We would like to develop an inclusive socio-scientific-entrepreneurial framework for the conservation, scientific research and development, and future application of the living root bridge technology. We also propose a statewide rural connectivity, conservation, livelihood and education project, which strategically combines scientific research with technology development and grass root entrepreneurship.



Keywords: *Ficus*, living root bridges, khasi, ancient technology, indigenous knowledge, tropical rain forest, conservation, ethno botany, economic botany, appropriate technology, rural connectivity, local enterprise, livelihood, natural economy, poverty alleviation, eco tourism, river systems, rural development, participatory methods

OBJECTIVES

Conservation objectives:

1. Conducting a statewide living root bridge mapping, ethno botanical and anthropological study to reveal the current state of these bridges, their overall performance and the local communities relation with these structures and the surrounding environment. This will lay a foundation for evaluating the scale of the conservation challenge and facilitate an appropriate local strategy. It will also reveal critical insights for scientific research and development, developing suitable entrepreneurial strategies, and implementing a state wide rural connectivity, conservation, livelihood and education project
2. Sharing this information with local communities, anthropologists, ethnographers, conservation experts, government agencies and UNESCO to spread awareness and create consensus for declaring these structures and surrounding landscape as world heritage sites
3. Interviewing and engaging local communities as part of an immersive ethnographic study and inquiry, to understand their concerns and reasons for neglecting these bridges or replacing them with conventional bridges. This information will help us align the conservation and entrepreneurial strategy with local needs
4. Developing a living root bridge 'manual' for documenting and preserving this knowledge
5. Consolidating this information for developing a framework for statewide social-engagement, which rebuilds community's connection with these bridges and repositions them as critical and unique grass root solutions of immense tangible and intangible value

Scientific objectives:

1. To develop a precise scientific understanding of *Ficus elastica* based living root bridges at all scales through a transdiciplinary study with experts from the fields of botany, ecology, structural and civil engineering, material science, social science, environmental science and architecture
2. To identify specific areas of significant scientific improvement in the living root bridge design and technology for improving, reviving and disseminating this keystone tropical plant specie and technology to re-establish its relationship with the people

3. To test and apply this technology for other native plant species e.g. *Ficus benghalensis*
4. To test and apply this technology for complementary plant species for growing food and other plant based material
5. To apply the improved living root bridge technology for a state wide *Ficus elastica* based rural connectivity, conservation, livelihood and education project. This will improve the socio-ecological resilience at a village and regional level
6. To apply this technology in other tropical and sub-tropical regions with specific focus on environmentally sensitive areas
7. To apply an improvised version of this knowledge for the urban and semi-urban context

Entrepreneurial objectives:

1. Aligning local economy with *Ficus* ecology for livelihood promotion and local enterprise
2. Potential adaptation of this technology as a host biome for orchids, mushrooms, other epiphytic plants and food for humans and other biota
3. Potential adaptation of the *Ficus* aerial root inosculation method for developing other structures, products and artefacts e.g. outdoor structures in parks and botanical gardens, furniture, lamps and fences
4. Developing a unique ecotourism initiative, which connects rural communities who grow these bridges with visiting groups in a sensitive and appropriate manner
5. Engaging rural communities in a state-wide rural connectivity, conservation, livelihood and education project for forest regeneration, river bank protection and soil quality improvement
6. Developing the 'living root bridge manual' into an educational and training tool for local youth and visiting groups as part of a 'living root bridge institute'
7. Creating a green infrastructure and design cooperative, which offers 'living plant based' solutions. Local community members are appointed as 'green engineers' and 'living plant based construction' experts who grow living plant based structures in other regions

Conservation

Task 1: Mapping, ethnobotanical and anthropological study of living root bridges in Meghalaya

Project scope: Carrying out precise mapping, ethnobotanical and anthropological study of **all** living root bridges in Meghalaya

Impact: The results will lay a foundation for conservation of living root bridges, engaging local communities for their protection, and sharing this information with all stakeholders for national and international policy level measures. This information will also act as a reference for achieving scientific and entrepreneurial objectives

Background: North-East India is one of the most remote, underdeveloped and ecologically sensitive areas of the country. Inhabited by indigenous tribal populations, and characterized by dense tropical rainforests, distinct orography, heavy monsoon rains, and vulnerability to landslides and flash floods, this region is at a threshold of transformation, with the nexus between poverty, population explosion and environmental degradation emerging as a critical threat to community based grass root practice of living root bridges. Currently eleven bridges have been documented by the author:

Location [Meghalaya, India]	Span [feet]	Growth stage	Safety level [5 is safest]
Riwai	75	Mature	5
Wahryngkoh	15	Mid life	3
Mawkyrnot	250	Early life	1
Mawkyrnot	150	Early life	1
Mawkyrnot	250	Mid life	3
Nongthymmai	60	Mid life	3
Nongthymmai	80	Early life	1
Nongthymmai	20	Mature	5
Nongriat	40	Mature	5

Nongriat	50	Mature	5
Nongriat	60	Mid life	3

Strategy: Based on information from various sources; there are numerous other bridges in different stages of growth across the state. The mapping process will include detailed survey and evaluation of these bridges based on the following parameters:

a) Overall location of the living root bridge and site conditions
b) Local climate and geography
c) Location of water bodies, sacred groves, markets, hospitals, schools and agricultural fields in the region
d) Local river features and hydrology pattern during monsoon season, especially frequency/severity of flash floods and storm surges
e) Proximity of surrounding villages and number of inhabitants
f) Demography and socio-economic status of local communities
g) Availability of alternative bridges in the region (alternative bridges include government built suspension bridges and community built bamboo bridges)
h) Overall growth stage and safety of the living root bridge (early, mid, mature)
i) Overall health of the bridge and its structural robustness
j) Plant and animal diversity seen on the bridge
k) Dimensions of the bridge (span, width, height of railing, height of bridge from river water level, average thickness of root fibres, density of root fibres, location of *Ficus elastica* trees, height of *Ficus* trees and geometry of the overall bridge morphology)
l) Frequency of use – daily footfall and quantity of load carried over
m) Original reason and justification for growing the bridge (rural connectivity to other villages, schools, hospitals and markets; For ecotourism?)
n) Current role and purpose of the bridge (Is it an alternative incase of failure of bamboo and steel suspension bridges; Is it critical or optional infrastructure solution?)
o) Process of site selection and growth of bridge
p) Degree of community involvement in bridge growth and management (Khasis are a matrilineal society and follow a village durbar system of governance, where a participatory method of governance is followed. We will conduct interviews with the village community and elders. Since number of families in most remote mountain villages range from 50 to 100, our sample size would be limited to this number)
q) Percentage of involvement of women and youth in bridge growth and management
r) Degree of migration from villages its impact on living root bridge management
s) Level of bridge consciousness and perceived value of these bridges (Based on our interviews and level of community engagement in the upkeep and maintenance of

these bridges we would like to assign a number to the strength of the relationship between these bridges and the communities, which use them)

t) Specific reasons for neglect of these bridges (Jhum cultivation has been suggested as one of the reasons during the author's preliminary field investigation and enquiry. Some other reasons include migration, changing relationship of the communities with their environment, changing sense of time, patience, and expectation, and perception of steel suspension bridges being more valuable and superior. These reasons need a precise investigation and the reasons may vary from one village to another)

Anthropological and Ethno botanical study of living root bridges and Khasi tribes

In addition to a precise mapping study, an ethno botanical and anthropological study will be carried out with specific focus on the following aspects:

a. Understanding the Khasi mind, especially Khasi perception of time, memory, cognition, space, material and sacredness
b. Understanding the Khasi relationship with the forest and plants
c. Ethno botanical perspective on the indigenous history, development, use and role of *Ficus elastica* and living root bridges
d. Understanding the connection between the practice of weaving within indigenou communities and how this would have influenced the design and growth of livin root bridges
e. Understanding the connection between various folk traditions and rituals, the khasi language and living root bridges
f. Understanding the relationship between local habitat design and living root bridges
g. Understanding the social organization behind growth of these bridges and if there is a compensation method
h. Understanding the philosophical meaning and relevance of the bridges in these communities (Are these performing as links between different social groups, stages of life, frontiers of territory, crops, natural resources?)
i. Understanding the rituals behind the growth process and how the community beliefs in spirits and an ecotheandric sacred worldview influences the bridge growth process
j. Comparing the Khasi worldview, weaving methods, rituals and living root bridge growth process with the Quechua people in Andes who build the Keshwa-chaca grass suspension bridges in Huinchiri, Peru.
k. Comparing the role of men and women, especially the bridge keeper in living root bridges with their role in grass suspension bridges of Peru.
l. Comparing the landscape and culture of Meghalaya and Andean region

Scientific research directions

A. Ecology

- Understanding the living root bridge ecosystem
- Understanding the ecology of *Ficus elastica*
- Understanding the keystone role of *Ficus elastica* and its contribution to water and soil conservation
- Understanding specific attributes of local conditions (soil, air, water and light), which are essential for growth and nourishment of *Ficus elastica*
- Quantifying the ecosystem services and other potential benefits of *Ficus elastica* based living root bridges
- Documenting the diversity of plants (including mosses) and animals that occupy and benefit from *Ficus* trees by sampling these organisms and getting them scientifically identified and documented
- Quantifying the socio-ecological resilience of *Ficus elastica* based living root bridges
- Investigating exact age of living root bridges and developing reliable growth models for establishing future bridges
- Developing an ecosystem model of living root bridge ecosystem to simulate and test future experiments
- Developing an appropriate conservation strategy for living root bridge ecosystem
- Developing a digital planning tool based on growth principles of *Ficus elastica* with local conditions (sunlight, nutrients, water, inosculation) as input parameters

B. Botany/Plant Science

- Understanding the growth and physiology especially morphology and biomechanics of *Ficus elastica* aerial root fibers
- Understanding the process of inosculation of aerial root fibers and specific attribute o *Ficus elastica*, which allows this
- Understanding deformation in *Ficus* plants
- Understanding the role of latex in *Ficus elastica*, and its contribution to overall performance
- Understanding the role of *Areca catechu* root guidance system and its interaction with *Ficus elastica* aerial root fibers
- Understanding gradual increase in thickness, strength, tensile stress and stiffness of *Ficus elastica* aerial root fibers in response to applied

load in the form of dead weight (soil, stones, timber) or stimuli resulting from anchorage or attachment

C. Biology

- Understanding the cell and tissue structure of *Ficus elastica* aerial root fibres during different growth stages, inosculation stage and under external environmental stresses from flash floods and storm surges

D. Civil and structural engineering

- Detailed survey and measurement of living root bridges and their geographical location
- Understanding the structural performance of living root bridges
- Highlighting key principles of structural performance and specific 'components' in the overall performance
- Quantifying load bearing capacity of the bridge and how it changes with time and aerial root growth/inosculation
- Understanding the role of geometry at macro and micro level within the living root bridge
- Understanding the principles and role of redundancy, irregularity and differentiation in achieving structural robustness
- Understanding change in structural performance over time and growth rate
- Understanding living root bridge capacity for energy dissipation, damping and robustness under extreme external stresses
- Understanding deformation in living root bridges and prevention of sagging
- Comparing living root bridge performance with other bridge typologies e.g. bamboo bridge, concrete-steel suspension bridge, concrete steel cable stayed bridge, steel truss bridge etc
- Detailed stochastic Finite Element Analysis of structural performance
- Engineering the bamboo scaffold and *Areca catechu* root guidance system using structural topology optimization

E. Material science

- Understanding the material attributes and behaviour of aerial root fibres
- Understanding the viscoelastic behaviour of aerial root fibre material
- Understanding variable stiffness and elasticity of aerial root fibres
- Understanding tensile stresses within aerial root fibres

- Calculating stiffness, density and modulus of elasticity of aerial root fibres
- Studying the self healing properties of the material
- Studying damage and its localized nature

F. Design and Architecture
    - Incorporating the knowledge from scientific research on living root bridges into living plant based architectural systems, which can enter mainstream infrastructure development projects and architectural solutions
    - Translating the knowledge from this research to classical engineered systems to ensure greater robustness and overall resilience
    - Leveraging principles of irregularity, differentiation and redundancy for novel structural systems within classical engineered systems
    - Investigating potential transfer of the living root bridge technolog within the urban environments at product scale and architectural scale

G. Environmental science
    - Lessons for sustainability and inclusive development
    - Lessons for construction and engineering in the context of natural hazards
    - Lessons for engineering and construction work in ecologically sensitive environments and developing economies

Reference links

1. First scientific paper on living root bridges: http://www.sanjeevshankar.com/pdf/Living-Root-Bridges-by-Sanjeev-Shankar-IABSE-Conference-Geneva.pdf

2. http://www.sanjeevshankar.com/living-root-bridges.html