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Indigenous Knowledge Systems and Formal Scientific Research for Climate Change

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ABSTRACT The paper is based on the spatial heterogeneity defined by indigenous and state government adopted scientific practices in tropical deciduous forests of Eastern Ghats in India, to demonstrate the way global ecological systems are increasingly being threatened. The objective is to develop a holistic research model based on different knowledge systems. Integration of indigenous knowledge systems (IKS) with modern scientific systems (MSS) has a great potential to strengthen socio-ecological resilience through the development of sustainable environmental management strategies. Although there is a broad consensus in scientific community, very few ecological studies have attempted a pragmatic and deep integration of these knowledge sources. Merging of two complex sciences is never an easy task, but if we are to move beyond for a greater understanding of the ecosystem complexities we should advance in the engagement of IKS and MSS on a more inquisitive platform. This paper produces a concept to synergise indigenous knowledge practices and modern ecological methods, for global climate change mitigation through forest management. It attempts to bring out convergent significance of both indigenous and scientific knowledge in improving the quality of ecological systems. Importantly it directs the practical inclusion of IKS as a worthy parameter into formal scientific research on climate change.

INTRODUCTION

Ecosystem changes due to rapidly transforming climate, is one of the threats to ecological balance we face today. Western science by itself is limited in addressing these issues, either through mitigation or adaptation, at any given local level. Indigenous knowledge systems (IKS) offer a wealth of natural observations for adapting to change in conditions through its dynamic nature and may provide a link towards mitigation (Green and Raygorodetsky 2010). These systems are known to possess great potential in providing good insight into the intricacies of local environment (Gadgil et al. 1993). Support for indigenous people and their knowledge in the management of global ecosystems is increasingly being recognized across the world (Ens et al. 2015). However, contrary to the expectations IKS may not always lead to solutions to ecological problems. Drastic changes in natural processes due to continuous and heavy human interventions outside the system render traditional practices non-resilient. Under these circumstances, integrating IKS and modern scientific systems (MSS) has been identified as a potential answer to address human needs and goals (DeWalt 1994; Klooster 2002; McGregor 2008). Often in the literature about the integration of IKS and MSS we encounter discussions such as creating new information and distinguished processes involved in including various stakeholders, but very few actually put their concepts to test. However, only a handful of studies suggest that we are just beginning to elucidate on the practicality of combining these two sources of knowledge (Kniveton et al. 2015; Schuttenberg and Guth 2015).

In this study the researcher plans to examine the possibility of an integrated use of indigenous and scientific methods to alleviate the degradation of deciduous forests of Eastern Ghats in India. These hill forests, with many rivers and streams, form important watersheds to the highly developed cities of the coastal plains. They provide agricultural irrigation, basic water supply for both drinking and domestic purposes, energy and food supply to major cities like Visakhapatnam. Rich in natural resources, endemic biodiversity and mineral wealth with lucrative commercial prospects for industries, these forests are under continuous anthropogenic pressure (Tauli-Corpuz and Cariño 2004). These contiguous hill forests are also a home to indigenous tribes with strong social cohesion and knowledge systems. Main livelihoods of the tribal people residing here are: settled agriculture, *podu* (shifting) cultivation and gathering of non-timber forest produce (Tauli-Corpuz and Cariño 2004). Since time immemorial they have been active participants in shaping forest structural and functional dynamics. Despite their interference and resource utilisation, sustenance of forest ecology and services was usually well ensured through their practices. But the increase in commercial exploitation of forests from outside, necessitated by growing demands of modern industrialization, disrupts ecological balance of these tribal forest systems.

The state ensured forest management in these areas through exotic timber plantations (to control soil erosion and gain economic benefit), coffee plantations (grown under the canopy shade of exotic *Grevillea robusta* and other wood yielding trees) and usage of exotic shrubs for soil binding, eco-tourism, and regulation of NTFP collection. Such practices are taken up with the best interest of bringing rapid economic development to the State (Timber, NTFP's, coffee beans etc.), modern development to tribal people and maintaining the forest integrity in these areas. However, they lean largely on need based principles offered by western science, which pivot around the notion that tribal people are incapable of handling their resources. Thus, a resultant mosaic of land use patterns emerged with very few and small primary forest patches interspersed (at high altitudes) among cultivated lands (slash and burn), plantations, secondary or post-extraction secondary forests. Though heavy land use practices are adopted in the region, there are no formal studies to evaluate ecosystem responses to these activities. We are unsure of the sustainability of ecosystem functions, services and the viability indigenous practices hold in these regions.

The proposed theme incorporates IKS and MSS to decipher ecosystems resilience under different land-use regimes and climate change for improving forest management practices. Eastern Ghats of India would provide an excellent opportunity with co-existing IKS and MSS. The researcher hopes that this study will enable the process of enhancing the value of poorly represented tribal people living in these areas.

Development of the Topic

Practical management of tropical forest biodiversity, for long-term sustenance of forest ecosystem services is a challenge, with continuing anthropogenic disturbance and changing climatic conditions. Managing these forests need a profound understanding of ecosystems process and function. Vegetation diversity, distribution and species ecological interactions play a key role in maintaining the ecosystem processes and biodiversity (Boulangeat et al. 2014; Valiente-Banuet et al. 2015). Any change in vegetation dynamics will resonate through all functional groups. Plant functional trait abundance and responses influence ecosystem processes more than species richness alone (Dìaz et al. 2001; Cadotte et al. 2011). Therefore, presence of key functional groups facilitates for resilient forests more than species rich areas (Filotas et al. 2014). Mechanistic insight into the links between plant diversity (both functional and species) and ecosystem processes is necessary for forest management (Dìaz et al. 2001). Despite high influential dynamics of climate change and land use management, their interactive effects on functional diversity and ecosystem processes have been less studied (Boulangeat et al. 2014). The researcher believes that strategies for improving ecosystem resilience and adaptability may be obtained, in some measure, from indigenous principles of forest management, as they possess a close understanding of complex ecological processes (Gadgil et al. 1993).

Historically with the advent of modern scientific systems, indigenous knowledge was considered inferior, insignificant and inefficient (Agrawal 1995a; Battiste 2002). Early theorists viewed traditional knowledge as an obstacle to economic development (Agrawal 1995b). This notion is still carried at present in some developing nations. Focus on the role of IKS in developmental progress of the world started out about 30-35 years ago (Briggs 2005). Indigenous knowledge systems were popularised as prominent sources of wisdom for sustainable development, particularly in the fields of agriculture, forest and land management, because indigenous people lived in harmony with nature since time immemorial (Warren and Rajasekaran 1993). Additionally, such consensus came from the view that traditional practices are a trial and error process of learning and adaptation, derived from a keen understanding of environmental complexity and flux (Ostrom 1990; Gadgil et al. 1993). However, evident limitations with exclusive use of IKS led to a recent increase in an alternative concept of combining practical IKS with experimental scientific methods, particularly for social and ecological aspects (Puri 2007; McGregor 2008; Kniveton et al. 2015). Although the importance of utilizing comprehensive systems science was well understood, pragmatic integration of two knowledge sources still remains elusive due to the difficulties in its application (Huntington 2000; Ens et al. 2015). For example, regional politics may form an obstacle to the realization of this concept. Hawley et al. (2004) explicitly described some basic hurdles to the association of traditional and science based environmental management systems. They emphasize that establishment of a unified management system requires strong foundation in mutual understanding, respect, honesty, trust and common goals.

In the last decade or so, we have seen a simultaneous evolution of concepts and sporadic elucidation of some case studies involving combination of IKS and MSS for environmental management (Huntington 2000; Klooster 2002; Puri 2007; Schuttenberg and Guth 2015). Merging of two complex sciences, however, is never an easy task and studies on practical involvement of the two sources, in most cases, are limited to simple aspects of participatory roles in resource conservation and management. Ens et al. (2015) stressed that active engagement of indigenous people and knowledge considerably improved the understanding and management of natural and cultural systems. Therefore, if we are to move beyond a superficial association, for a deep understanding of the complexities of natural ecosystems order, we should advance in the engagement of these knowledge sources on a more inclusive platform. It is believed that with rapidly changing climate conditions it is more imperative now to progress into complex scientific systems given by Filotas et al. (2014) that involve various sources of information and methods, for an effective management and adaptation to environmental change. Green and Raygorodetsky (2010) also stress the need for an active integration of IKS in formal climate change research and education.

Current or Proposed Solutions

Study Area in Detail

Eastern Ghats (EG) are the long discontinuous chain of hills that run parallel to the east-coast line of the peninsular India. These ranges can broadly be divided into northern, middle and southern EG. The northern portion extends from the River Mahanadi to the River Godavari covering Odisha and parts of Andhra Pradesh (AP) States. The middle EG extends from the River Krishna towards the city of Chennai, Tamil Nadu. The southern part runs westwards meeting the Nilgiri Ranges of Western Ghats. Eastern Ghats are one among the oldest geological formations of the world (Pullaiah and Sri Ramamurthy 2002). They are older than the Western Ghats and the Eastern Himalayas within India but they always remained neglected for protection (Reddy 2006). The over-arching biodiversity hotspots of Western Ghats and Eastern Himalayas have long grabbed the attention for conservation in India. However, Eastern Ghats are rich in mineral resources, forest wealth and hold important endemic species and need conservation efforts. Majority of the forests in EG, particularly in the northern portion, now remain degraded due to commercial prospects of these hills, with low priority for their protection.

Eastern Ghats experience tropical monsoon climate, with varying degrees of temperature and rainfall throughout. Pre-summer temperatures on average may range between 20 - 35 ÚC indicating a north to south increasing trend. During summer temperature increases up to 43 ÚC and in winter it decreases to even 2 ÚC at night (Pullaiah and Sri Ramamurthy 2002). The Ghats receive extended rainfalls from southwest monsoon, mid-June to late September, and also during its retreating phase (northeast monsoon) from October to December (Kohli 2002; Pullaiah and Sri Ramamurthy 2002). Cyclonic storms and heavy rainfall in winter characterize Eastern flanks and the Coastal plains. Northern parts get rainfall of about 1000-1700 mm, while central and southern parts receive 600-1050 mm annually.

The hills covering the four most northern districts within AP state, that is, Srikakulam, Vizianagaram, Visakhapatnam, East Godavari, contained some of the best contiguous forested areas of EG. These areas are home to some of the globally threatened species of birds such as the Purple wood pigeon, Malabar pied hornbill, Forest owl and habitat destruction is an impending concern. Apart from rich flora and fauna, North coastal districts of AP support substantial indigenous population (96,000 according to 1995 census), belonging to 39 tribes, such as Kondareddies, Kondadoras, Bagatas, Jatapus, Savaras, Khonds, Parjas and Valmiks etc. (Tauli-Corpuz and Cariño 2004). They predominantly live in hilly and thick forest regions and economically depend only on agriculture and non-timber forest products. Slash and burn or shifting cultivation is the predominant means of agriculture for tribal people, which is strongly restricted by the forest department, citing deforestation and soil erosion caused by such practices. Therefore, settled agriculture was promoted within the restricted areas. However, an increase in the population of tribal people added to their woes of expansion. In addition, increase in mining activity by the government and monoculture plantations (coffee, timber etc.) initiated by forest department, to gain economic development, has now led to a reduction in the spatial area for dynamic shifting agricultural practice. Therefore, once sustainable practices of indigenous people have become ecologically and economically unviable, it forces them out of forests. This leads to a long standing conflict between the state and indigenous tribes for land ownership. But it was noticed that some areas exist where tribal people practice slash and burn cultivation, particularly in high altitudinal ranges. Therefore at present there is a serious decline in the indigenous population living on the forests largely due to the immense discouragement to their way of life and practices. This poses a serious threat to the survival of indigenous people and their knowledge systems. The researcher hopes this project will initiate addressing of conservation issues with an immediate effect in these regions.

Forests that run down from Odisha into AP through these districts show signs of progressive degradation. East Godavari and some regions of Visakhapatnam still contain natural forest patches which soon might be serving profit-making interests of the nation, as these ranges are particularly rich in bauxite reserves. Ranges present here provide an excellent opportunity to understand the spatial transitioning effects of intact to degraded forests. The researcher will select the study sites within the broad region between Sileru (18° 02' 52.86" N, 82° 02' 02.18" E) in the North, Yarala Gadda (17° 41' 19.97" N, 81° 57' 29.82" E) in the East, Maredumilli (17° 35' 53.49" N, 81° 42' 48.85" E) in the South and Donkarayi (17° 55' 45.05" N, 87° 47' 57.72" E) in the West, provides a mosaic of land use practices ideal for this study.

Proposed Concept

Understanding the complexity of core ecosystem behavior naturally and in response to external environmental changes is inconceivable, but provides us with an insight to maintain ecosystems within their resilience thresholds. With an increase in the degradation of forests, it has become imperative to manage ecosystem function and services. Involvement of different knowledge sources (complex systems science) to formulate adaptable practical solutions and manage forests in view of climate change is the need of the hour. Environmental management studies related to the integration of IKS and MSS have largely relied on a sociological view, rarely engaging with scientific ecological component. Recently, Roba (2008) provided a model involving the use of scientific ecological methods and local perspectives in ground level implementation of global environmental programs. This inclusion is a start for a deeper integration of these two different approaches. The researcher advances to understand dynamics of forest ecosystems through complex systems science perspective, which will include IKS and MSS. The basic conceptual model works on the interface of forest land-use systems (management practices, IKS and MSS) and plant community dynamics (ecological science) to infer upon ecosystem properties (forest resilience under climate change) (Fig. 1). Broad scale model, specific to the study, shows interacting response and effect relationship between land use practices, vegetation dynamics/ecosystem process and climate change (Fig. 2). Their uses in modelling predictions for ecosystem change mitigate climate change effects. An example is this methodological framework, which integrates indigenous knowledge with scientific methods, to derive natural resource management strategies for tropical deciduous forests of Eastern Ghats. Proposed framework can be utilised for any ecosystem with a co-existence of different land-use practices through different management sources. Additionally, the basic concept presented can be hand crafted to broader applications based on the study concerned, for example: certain elders from the pastoral community in Kutch district, Gujarat have the knowledge to develop buffalo breeds which can produce good quality milk (pers. com.). This can be tested and developed through a more acceptable scientific ge-

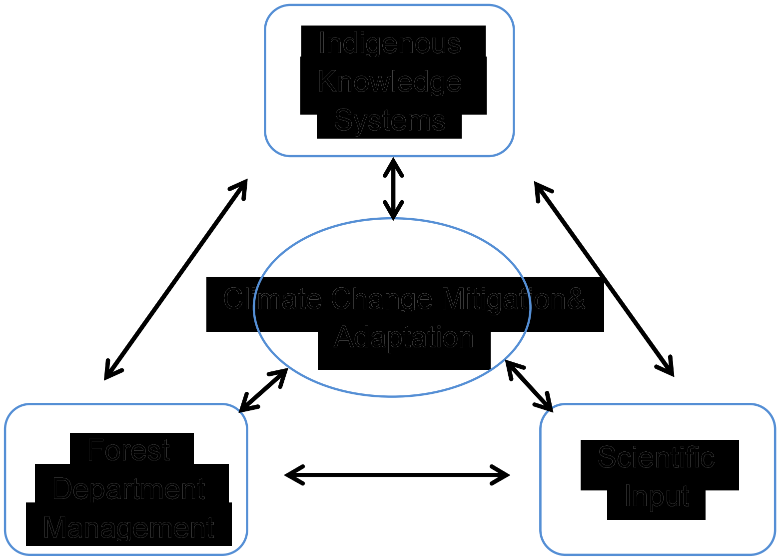

Fig. 1. Basic conceptual framework shows working relationship between different aspects on which the proposed project functions
Source: Author

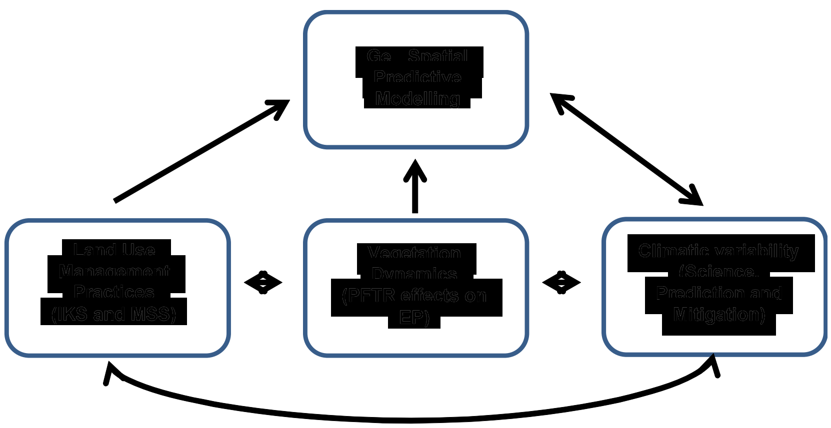

Fig. 2. Broad conceptual model behind the present study, showing the relationships between land use and climate change with their interactive effects on ecosystem processes through changes in vegetation dynamics. Indigenous knowledge systems (IKS) and government departments' version of modern scientific systems (MSS) are two major land use practices continuing at present in the Eastern Ghats of North coastal districts of Andhra Pradesh. Noted are the effects of plant functional trait response (PFTR) on ecosystem properties (EP).The directions for the utilisation of this information in geo-spatial modelling to predict climate change effects on these systems, are also given.
Source: Author

netic study with integration of the systems. Such initiatives will enable integration in a true sense, until the boundaries between the two sciences are blurred and common goals develop.

Proposed Objectives

- To identify indigenous land use systems and forest department management practices in the study areas: the differences between systems and the way they work, towards an end to understand ecological significance of these systems and potential adaptation of IKS derived management into mainstream ecosystem conservation science.

- To assess the effects of land-use and forest vegetation on ecosystem services, particularly carbon sequestration, of the region and assess seasonal variation and land use on carbon storage.
- To assess the after-effects of a land use practice on vegetation diversity, composition and regeneration and, ecosystem properties; and vulnerability of abandoned sites of different land-use types to invasive species.
- To assess the indirect spatial effects of land-use practices on natural vegetation diversity and growth and understand the effects of site level competition for plant available resources between forests and land uses.
- To predict landscape scale changes across ecosystems using simple spatial and temporal models and ecosystem response to land-use and climate effects will inform on alternative management solutions to decision makers.

METHODOLOGY

Site Selection

All the sites, that is, intact forests, cultivated lands, plantations and degraded regions, with an area of 1 ha or above only will be considered for this study. It is important that the researcher considers these sites with similar topography (elevation, slopes), hydro-climatic conditions (rainfall, proximity to both ephemeral and perennial streams), forest types (moist or dry deciduous), and forest understory (grassy or forested formation) to eliminate obvious bias. Forests of these Ghats predominantly consist of moist deciduous forests, dry deciduous forests and some patches of interspersed savannas. Deciduous forests in these regions may have both grassy and forested understory formations. Open, dry savanna patches are formed after repeated disturbances largely due to shifting cultivation practices (as defined in the forest department's working plan). The study will be in the tropical moist deciduous region and compare the effects of land-use to intact forests with herbaceous understory or forested formation, as it will provide a true forest semblance for comparison. This will be particularly useful to select the control plots for addressing questions given below.

Sites will be selected carefully with joint discussions with forest department and local indigenous people. Potential sites may preliminarily be identified based on the Moderate Resolution Imaging Spectroradiometer (MODIS)-Normalised Difference Vegetation Index (NDVI) vegetation maps, temperature and rainfall data across the area. However, it is difficult to differentiate between plantation and forest types through NDVI maps. The data points obtained from the forest department, for the plantation sites they hold, can be of use to identify forest areas, through elimination process. The researcher believes that involving tribal people and forest department staff into discussions will be crucial to identify the field sites. Informal surveys with the help of both groups can add further insights into the managed areas, for example, to check if the potential plantation site will not be harvested within project period. Once the potential sites across the landscape are identified the researcher will first map the boundary of the site. In places very large at least 1 ha plots will be mapped around the central point.

General Sample Design

A 10m × 10m grid over the Geographical Information Systems (GIS) maps of the study area. Within the 1 ha plot, three 10m × 10m grids will be randomly selected, mapped and marked physically. These three grids will serve as a sub-plot to collect tree data, all live trees (above 1.3 m in height and greater than or equal to 10 cm in GBH) and lianas will be enumerated, tagged/paint marked, mapped, measured, installed with dendrometer bands and monitored. Dendrometer bands are used to measure radial growth and are installed by using standard protocols developed by CTFS. The method used for laying grids will be followed equally for the crops in cultivated lands. To account for understory plant species and seedlings or ground vegetation within croplands four 1m × 1m quadrats will be placed in four corners within each 10m × 10m grids that were chosen for tree evaluation. Soil cores up to a depth of 1 m will be collected from five predetermined locations within each 1 ha plot to characterize physical and chemical properties. Adequate number of erosion pins will be employed on the top-end and bottom-end boundary of the site to assess annual variability in soil levels due to land-use type. The general design for sampling will be used wherever applicable according the questions being addressed in this study.

Measurements

Measurements will be taken once every three months such that fine scale seasonal variations can be recorded. Data will be collected both at the site level and plant level (to estimate plant functional trait relationships with ecosystem properties).

Site Level: Soil physical properties such as texture, infiltration, water holding capacity, moisture, water potential etc. and chemical properties soil organic carbon, nitrogen, potassium. Soil erosion potential, litter biomass will be noted.

Plant Level: Plant functional types are usually defined according to leaf habit (broadleaf, simple, compound, needle leaf), leaf life span (evergreen, deciduous) and life form (tree, grass, herbs, shrubs, lianas), habit (ephemeral, perennial, annual etc.) (Reichstein et al. 2014). Seedling recruitment, growth and survival will also be taken. In addition above ground growth variables, such as absolute growth rate (AGR) and relative growth rate (RGR) will be calculated. Data on specific leaf area, girth at breast height, height of tree, canopy dimensions, bark thickness and wood density will be recorded. Change in diametrical growth will be measured for all the trees within 10m × 10 m grid, while the rest of the plant functional traits will be measured for five individuals of most dominant species in the within the 1 ha plots.

DISCUSSION

The findings are anchored on the following stages:

Understanding Land-use Practices

First step towards understanding the effects of land use practices on the vegetation and ecosystem is to study the management practices thoroughly. The interaction with local communities and forest departments from the initial stages of the project will be crucial in exploring and identifying study sites, understanding management structure and practices, gaining knowledge on ecological basis for the use of such practices (rainfall, soil types, fertile patches etc.,) and their dependence on the forests. Additionally, using indigenous knowledge on land degradation, ecological indicators, impact of their practices, ecological monitoring methods may also lead us to improve our research design. The study will not be limited to utilizing support from indigenous knowledge for implementing the framework, but will attempt to understand the ecological observations behind their practices and try to assess the viability of their insightful options under rapid changes in climate and natural systems. Some of the common methods to address issues towards this end are secondary research, semi-directive interviews, questionnaire surveys, workshops and joint field assessments (Huntington 2000). However, Roba (2008) gave a clear and elaborate perspective of difficulties ensuing in integration of IKS, and reckons that "the most appropriate forum for using participatory methods is organized workshops involving local and technical groups for one to one discussions". Therefore, the above approach will be adopted in the study. However, we would continually involve local participation through joint field assessments and present our results periodically through workshops.

What are Effects of Land-use Practices?

The researcher would like to assess the role of different land-use types on carbon sequestration. Find if dominant plant functional groups from these land use types have an effect on basic ecosystem properties. The site selection and sampling will be made according to the methods explained under 'sampling design'. The following four land systems will be considered as one block unit which will be replicated three times within the study area.

i) Intact forest-control,
ii) Cultivated lands-indigenous land use type,
iii) Plantations-department management,
iv) Open grassy savanna-completely degraded (if present in the area)

Each land system is considered a plot/site. The homogeneity of topography and hydro-climatic conditions within each block will be ensured.

Grassy savannas are often considered to be formed in highly degraded regions of the area. However, it has been found that grassy lands have greater infiltration rates than plantations (Krishnaswamy et al. 2006). This study will help understand if these regions are degraded or could be an alternative stable state.

What are the Effects of Abandoned Land-use Areas?

The second objective is to understand the effects of cultivated and plantation lands on vegetation and micro-ecosystem properties, post abandonment. In this the researcher will address the following questions that help to understand the severity of the degradation these land-uses may leave behind: Is there a difference in the vegetation diversity and composition, particularly understory species, from undisturbed forests, in these abandoned areas? How prone are the abandoned lands to invasive species and soil erosion degradation? Is there a difference in this vulnerability between cultivated and plantation plots when compared to intact forests?

The researcher will assess plant diversity in the abandoned areas that are left undisturbed further after abandoning. The researcher will select plantation and cultivated plots of uniform age post abandonment and take intact forests as control. A set of these three system plots will be considered as one block and the researcher aims for three replicates of such block units. Similar to the aforementioned, sites from homogenous conditions will be considered within one block. In addition to the plant functional traits described earlier, the researcher will record the origin (native and non-native), invasiveness (invasive and non-invasive) of the plants and seedlings in the abandoned plots.

What are the Effects of Land-Use Types on the Forests?

The third objective is to report on the land-use impact on surrounding forests. The researcher believes that this approach would provide better insights into the effects of timber plantation and forests. In this the researcher would like to answer questions such as: 1) Do fast growing exotic tree species in plantation plots, access resources fast to effect growth of forest trees (indirectly carbon sequestration)? 2) How do plantation species affect surrounding vegetation diversity and growth compared to cultivated crops?

In a paired land-use type approach the researcher addresses these issues. The researcher aims to select compound plots with a paired cultivated or plantation area associated forest patch adjacent to one another (200-500 m apart) and a homogenous forest area as control. The effects of only active plantation and cultivation sites on natural vegetation surrounding them will be considered.

CONCLUSION

The concept suggests that with considerable effort it is possible to make indigenous people and knowledge systems an integral part of scientific approach. Biological scientific perspectives can benefit through improvement in its strategies by reaching out to other knowledge systems. Throughout history, indigenous people and their knowledge systems were suppressed as inferior and inefficient. We produced a concept to synergize indigenous knowledge practices and modern ecological methods, for global climate change mitigation through forest management. It brings out the convergent significance of both indigenous and scientific knowledge in improving the quality of ecological systems. Importantly it directs the practical inclusion of IKS as worthy parameter into formal scientific research on climate change. Although some might disagree over unequal acceptance of IKS to that of MSS, this is dependent on the topic considered and ecological viability of indigenous options present. Taking an important step for the advancement in research oriented inclusion is necessary. No longer can we continue to protect and manage our resources based on a top-down approach, there is a need for bottom-up approach to balance the equation.

RECOMMENDATIONS

The paper recommends that it is important for IKS to find a hold on par with mainstream MSS in policy and decision making to bring out value to indigenous people and their confined systems, particularly on ecological aspects. The best possible way to engage these systems is by proving their worth through test. Scientific systems though projecting a “know it all” stance are constantly in need of supportive information to arrive at conclusions. Therefore, it is recommended that integrating IKS and MSS can form a mutually beneficial association. So far attempts to realise this association are done at a very minimal level. If we are to reap benefits by merging the two knowledge sources they should be involved on a more inquisitive platform.

The paper further recommends that representation of IK based studies should not be left confined and inaccessible. However, it should be represented in an equal and prominent form with scientific systems to derive solutions for the problems we face in modern day. It is simple now to do so, as modern scientific approaches have become more receptive and cautious of their actions on ecology and environment.

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