Sustainability Research Institute

SCHOOL OF EARTH AND ENVIRONMENT

UNIVERSITY OF LEEDS

The role of livelihood assets in influencing spatial choices for REDD projects at subnational level: a case study from Kenya

Joanes O. Atela, Claire H. Quinn and Peter A. Minang

June 2014

Sustainability Research Institute

Paper No. 66

SRI PAPERS

SRI Papers (Online) ISSN 1753-1330

First published in 2014 by the Sustainability Research Institute (SRI)
Sustainability Research Institute (SRI), School of Earth and Environment,
The University of Leeds, Leeds, LS2 9JT, United Kingdom

Tel: +44 (0)113 3436461
Fax: +44 (0)113 3436716

Email: SRI-papers@see.leeds.ac.uk
Web-site: http://www.see.leeds.ac.uk/sri

About the Sustainability Research Institute
The Sustainability Research Institute conducts internationally recognised, academically excellent and problem-oriented interdisciplinary research and teaching on environmental, social and economic aspects of sustainability. We draw on various social and natural science disciplines, including ecological economics, environmental economics, political science, policy studies, development studies, business and management, geography, sociology, science and technology studies, ecology, environmental science and soil science in our work.

Disclaimer
The opinions presented are those of the author(s) and should not be regarded as the views of SRI or The University of Leeds.

The role of livelihood assets in influencing spatial choices for REDD projects at subnational level. A case study of Kenya

Joanes O Atela[1,2*] Claire H Quinn[1] and Peter A. Minang[2]

[1]Sustainability Research Institute, School of Earth and Environment, LS2 9JT, Leeds, UK

[2]ASB- Partnerships for the Tropical Forest Margins, World Agroforestry Canter, PO Box 30677-00100, Nairobi, Kenya

* Corresponding author email: eejoa@leeds.ac.uk

Contents

Abstract

Reducing emissions from deforestation and forest degradation (REDD) is globally supported as a cost effective programme that could achieve global mitigation and spur pro-poor socio-economic development in developing countries. Various multilateral, private and public sector actors are now keen to lobby and disburse REDD demonstration funds on the premise of spurring pro-poor carbon investments in less developed areas that were otherwise excluded from the Clean Development Mechanism. An understanding of the spatial targeting of REDD projects relative to subnational socioeconomic conditions may generate specific lessons for refocusing national REDD policies. This paper focuses on Kenya as a case study to analyse how REDD projects are distributed across quantified sub-national vulnerability indices. A vulnerability index map for Kenya was first developed from long-term socio-economic (crop yields, literacy rates and poverty rates) and climate (rainfall and temperature) data drawn from the 47 counties of Kenya. The number and nature of REDD projects were then located on the vulnerability map. Correlation tests were performed and experts consulted to clarify the socioeconomic features of vulnerability that significantly influence spatial choices for the REDD projects. Results show that a significant number of REDD projects are located in relatively low-vulnerability counties. Projects' nature, objectives, stakeholders and standards were similar across the vulnerabilities. However, correlation tests revealed that the low-vulnerability counties, hosting more projects, are endowed with humid forest resources, secure land tenure and better access to water. Experts suggested that such conditions posit low transaction costs and higher carbon revenues for profit-seeking projects that currently dominate the demonstration activities. Conversely, medium-high-vulnerability areas potentially provide low opportunity cost for REDD project and enhances synergies between mitigation and adaptation. National REDD policies should therefore direct REDD funds to vulnerable areas, with mitigation potential. More targeted field-based studies on the practical interaction between projects and local socio-economic conditions can be formulated from these findings.

Keywords: forest resources; pro-poor; REDD projects; spatial targeting; socioeconomic

Submission date: 27-02-2014; Publication date: 05-06-2014

About the Authors

Joanes Atela, is a final year PhD student in Environment at the Sustainability Research Institute, Leeds University. His research focuses on the implications of global forestry carbon offsets on the local livelihoods of sub-Saharan Africa. He is also a PhD fellow with the ASB-Partnership for the Tropical Forest Margin at the World Agroforestry Centre (ICRAF). He has a BSc in Environmental Science and MSc in Tropical Agriculture and Resource Management. Joanes has over three years research experience on payment for ecosystem services and governing community based natural resource management.

Dr Claire Quinn is a lecturer at the Sustainability Research Institute Leeds University, UK. She is an ecological social scientist with over 10 years of experience working on interdisciplinary projects in Africa and the UK. Her research interests lie in the links between ecological and socio-economic processes in the management and conservation of natural resources. Specifically Claire's research focuses on the distribution of property rights in multi-resource systems and the implications for management; and livelihood vulnerability and adaptation to environmental change in agricultural communities.

Dr Peter Minang is the global Coordinator of the Alternatives to Slash and Burn-Partnership for the Tropical Forest Margin at the World Agroforestry Centre. He is the leader of ICRAF's Science domain 5 'Environmental Services'. He has over 15 years of experience working on Clean Development Mechanism (CDM) forestry, community forestry, environmental education, and watershed management. Peter's current research interests include the linkages between reduced emissions from deforestation and forest degradation, poverty reduction, and environmental services. He is also very interested in the application of participatory GIS in natural resource management.

1 Introduction

Reducing emissions from deforestation and forest degradation (REDD) is a globally emerging forest programme aimed at mitigating climate change and promoting development in developing countries (Mbow et al. 2012). REDD has attracted international legitimacy as a pro-poor climate policy that links carbon management to human development. The ability of REDD to achieve emission reductions and at the same time spur socio-economic development in developing countries is considered crucial for the programme's success (Stern 2006).

Various actors are now keen to lobby and disburse REDD demonstration funds on the premise of spurring pro-poor carbon investments in less developed areas that were otherwise excluded from the Clean Development Mechanism (CDM) of the Kyoto Protocol. Consequently, a diversity of REDD demonstration projects has emerged in practice (Angelsen et al. 2009). In this paper, we broaden the scope of REDD demonstrations projects to include both forestry and agroforestry projects that are selling or are designed to sell carbon credits and could potentially generate lessons for a formal national REDD programme. In the 2012 survey of forestry carbon projects, agroforestry practices were reportedly inherent within most REDD projects and were used to promote alternative community livelihoods (Peters-Stanley et al. 2013). Most of the agroforestry activities and their associated emission reductions and co-benefits were monitored and verified using methodologies that are similar to those of REDD.

Negotiations at the United Nations Framework Convention on Climate Change (UNFCCC), have broadly institutionalised safeguards (UNFCCC 2010; decision 1/CP.16) and the additional recognition of communal forestry and co-benefits 'REDD+' (UNFCCC 2009) as pro-poor considerations in REDD. The 17th Conference of Parties (COP) to the UNFCCC (UNFCCC 2012; decision 2/CP17) also recommended that Parties and concerned organizations should promote equitable distribution of sustainable development resulting from climate funds. A range of multilateral funds, public and private sector funds have since emerged to demonstrate how REDD could achieve mitigation and development. Examples of

such funds include the UN-REDD (UN-REDD 2008), the World Bank's Bio-Carbon Funds (World Bank 2011) and the Forest Carbon Partnership Facility (FCPF et al. 2010) and a host of private and public sector support to sub-national projects.

REDD demonstration activities supported by the above funds are distributed across developing countries. This distribution is well documented in research articles (Peters-Stanley et al. 2013; Cerbu et al. 2011; Diaz et al. 2011) and updated within global databases e.g. CIFOR's global database for REDD+, Ecosystem Marketplace among others. The databases and related literature show that, the simplified and diversified funding opportunities, within REDD potentially enable poor countries to access carbon funds if compared to the CDM (Bond et al. 2009, Diaz et al. 2011). Within sub-Sahara Africa, Kenya, South Africa, Tanzania, Democratic Republic of Congo and Uganda are among the leading producers of REDD related carbon credits (Peters-Stanley et al. 2013; Diaz et al. 2011). However, at sub-national level, little is known about the spatial distribution of existing REDD projects across varying socio-economic and biophysical conditions.

1.1. Background

At the project development level, pro-poor benefits and emission reduction potential are the key criteria used to geographically and conceptually justify the location of REDD projects. Areas endowed with forest resources are mainly justified for REDD because they potentially enable project performance in reducing emissions. Specific case studies such as Tanzania (Lin et al. 2014) and East Kalimantan, Indonesia (Harris et al. 2008) show that areas with higher forest density/higher carbon stocks are prioritized for REDD. However, various forest types including tropical equatorial forests, tropical dry-land forests, tropical seasonal forests and even plantation forests, are all recognised under REDD even though they have varying mitigation potentials (Gibbs et al. 2007).

In terms of pro-poor benefits, project proposals often cite poor socioeconomic developments, poverty and limited economic opportunities as justifications for the need for REDD funds in particular areas (Cerbu et al. 2011). The decision of project investors to be pro-poor in committing REDD funds is crucial because the relative socioeconomic conditions of various areas influence project's opportunity cost and security of REDD investments (Lin et al. 2014) thus determine the overall success of

the project (Blom et al. 2010, Engel et al. 2009). Nonetheless, poverty alleviation and pro-poor development are reportedly key motivations for donors to fund/ support particular REDD projects within a country or a region (Cerbu et al. 2011). Pro-poor targeting for REDD projects, in practice, is additionally justified around social justice in the fight against climate change. In this social justice, REDD project funds are expected to spur additional socioeconomic development and improve the natural capital base thereby increasing the adaptive capacity of communities living within particular developing countries. Such socio-economic developments are linked to reduced vulnerability to climate change (Eakin and Luers 2006; Robinson and Berkes 2011). Vulnerability here refers to the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. The vulnerability of a community or a system depends on how its key livelihood/economic activity is exposed, sensitive and able to adapt to climate change (IPCC 2007). As such vulnerability provides a holistic integration of socioeconomic conditions.

In the context of climate change, developing countries - where REDD is to be implemented – are relatively poor and vulnerable to climatic changes. The livelihoods of these communities mainly depend on rain-fed agriculture- a sector that directly depends on climatic variables such as rainfall and temperature (IPCC 2007). Even within particular developing countries, different communities experience different levels of vulnerabilities subject to their varied socio-economic status (World Development Report 2008; IPCC 2007, Barrios et al. 2008b). For instance, some developing countries such as Kenya are reportedly very structured in their wealth status (World Bank 2009). This structured intra-state vulnerabilities have been assessed in particular sub-Saharan African countries such as Ghana (Antwi-Agyei et al. 2012) and South Africa (Gbetibouo et al. 2010). The assessments have relevantly applied agricultural, socio-economic and climate data to even index relative sub-national vulnerabilities. Linking mitigation and adaptation policies to such vulnerability assessments structures is recommended as a way of informing policy reforms and interventions towards vulnerable communities (Fraser et al. 2013) and a means to informing synergies between climate change mitigation and adaptation (see UNFCCC 2012). Therefore, an understanding of how the current REDD investment patterns play out with sub-national biophysical and socioeconomic

features of vulnerability is necessary to inform specific pro-poor actions within national REDD policies.

This paper focuses on Kenya as a case study to link REDD interventions (projects) to quantified sub-national vulnerabilities. The overall objective of the paper is to characterise the socio-economic conditions that might influence the ability of communities to access the expected globally designed REDD investments. The specific objectives are: (1) to develop a sub-national vulnerability index map for Kenya; (2) to locate the nature and types of REDD projects on the vulnerability map; and (3) characterizing the relationship between vulnerability and the spatial location and design of REDD projects.

Kenya actively engages in REDD demonstrations (Diaz et al. 2011) and policy processes under the FCPF REDD preparatory fund of the World Bank. Therefore we believe that other countries especially those of sub-Sahara Africa may adopt lessons from this case study. More details about Kenya and the rationale for selection her as a case study are discussed in the next section alongside the methodological steps. Results, discussions and conclusions then follow respectively.

2 Materials and Methods

2.1. Study area

Kenya is located to the East of Africa at 0.4252° S, 36.7517° E. The country is administratively divided into 47 counties making up a total of 8 provinces (Republic of Kenya, 2010b). The country's population currently stands at 41 million persons, 77% of whom live in rural areas. Forty three percent (43%) of the rural population, as of 2011, live below the poverty line (US$1.25 a day) (Kenya National Bureau of Statistics 2011). Kenya's economy is natural resource driven. Agriculture and tourism are the main contributors to GDP. Agriculture contributes about 25% of Kenya's GDP and also supplies numerous non-marketed goods and services to the country's rural population (Republic of Kenya 2010). Eighty percent (80%) of the country's land is classified as semi-arid to very arid (ASALs) while humid conditions are found in the central and western highlands. Crop cultivation is mainly dominant in the humid zones while the ASALs are favoured by agro-pastoralists. However, rainfall variability has been highlighted as major cause of vulnerability to the

livelihoods of many Kenyans with famine frequency narrowing from 20 year cycles (1964 – 1984), to 12 years (1984-1996) to two years (2004-2006) and lately to a yearly interval (2007/2008/2009) (Republic of Kenya, 2010a). The Kenyan government has put in place a national climate change response strategy (Republic of Kenya, 2010a), that highlights cross-sectorial mitigation and adaptation options.

Kenya's resource base consists of national parks, wildlife and forests. The country's forest cover has declined from 13% at independence- five decades ago to a current 6% (FAO 2010). Deforestation is thus a major concern and is primarily caused by conversion of forest-land to small-scale agriculture and by illegal logging. To improve forest management, the country recently amended the forest laws (Forest Act 2007) to decentralize forest management. The new laws legalize the establishment of Community Forest Associations as the local institutions that administer communal-based forest management. The climate change response strategy envisages carbon offsetting and particularly REDD-related programmes to promote forest cover, mitigate climate change and provide multiple benefits (Republic of Kenya 2012a). Kenya is getting ready for REDD through the UNFCCC negotiations and within the World Bank's Forest Carbon Partnership Facility. The country's climate change action plan (GoK 2012a) prioritises REDD as a low carbon development pathway and an opportunity to attract international funds for development, green jobs and achievement of the country's Vision 2030. The country is a leading adopter of REDD demonstrations and delivered 64% of sub-Sahara Africa's REDD related forestry credits in 2010 (Diaz et al. 2011).

2.2. Methodological steps

Three steps, corresponding to the study objectives, were applied in data collection and analysis: (1) developing a vulnerability index map of Kenya (2) locating REDD projects on the vulnerability map (3) characterizing the relationship between vulnerability and the spatial location and design of REDD projects.

Step 1: Developing a vulnerability index map for Kenya

In selecting a suitable approach to vulnerability indexing, we first reviewed existing literature to understand the varying notions on how to measure vulnerability. Approaches to vulnerability assessment/indexing include variable assessment and

the indicator approach (Gbetibouo et al. 2010; Füssel and Klein 2006). The variable assessment applies generic and rather holistic simulations to point out areas where greater climate impacts are eminent (see Ericksen et al. 2011). The variable approach is however broad-scaled and excludes specific contextual factors that usefully influence vulnerability (Luers 2005). The indicator approach applies a set of proxy indicators to calculate vulnerability at various scales (Eriksen and Kelly 2007, Luers et al. 2003). In this study, the indicator approach was preferred because it is applicable at various scales and thus informative to national policies (Leichenko and O'Brien 2002). The indicator approach has been applied in indexing food vulnerability in sub-Saharan African countries such as Ghana (Antwi-Agyei et al. 2012) even though it is arguably subjected to limited availability of proxy socio-economic data especially in the region. Vulnerability was derived from exposure, sensitivity and adaptive capacity indices calculated for each of the 47 counties (IPCC 2001). Rainfall/temperature, maize yield and socioeconomic data were used to calculate exposure, sensitivity and adaptive capacity indices using the following the steps:

Exposure index: We referred to Füssel and Klein (2006) to define exposure index as the degree to which agricultural productivity (maize yields) is exposed to climatic changes. Both rainfall and temperature exposure indices were calculated and compared on account of their significance to sensitivity. We obtained 41 year (1970 - 2010) monthly rainfall and temperature data for the 47 counties from the Kenya Meteorological Department in Nairobi (Kenya Meteorological Department 2012). From the data, a 30-year (1971-2000) average rainfall for maize growing period was assigned as a standard reference against which yearly rainfall variations were compared (see Simelton et al. 2009). The standard 30-year was calculated for the maize growing seasons falling within March – November each year including both short and long rainy seasons. Following Simelton et al. (2009), the 30-year standard average was divided by the 'actual' amount of rainfall observed during the same growing periods (March – November) for each year to calculate exposure index for each year (eq. 1). Temperature based exposure index was also calculated using the same procedure (eq. 2) and as illustrated in Hawkins et al. (2013). The significance of rainfall and temperature exposure indices to changes in crop yields were compared and the most significant index applied in the vulnerability indexing.

Exposure index _prep = sum for the critical growing period/mean of the standard 30 year rainfall for the critical period.......eq. 1

Exposure index _temp= sum for the critical growing period/mean of the standard 30 year temperature for the critical period.......eq. 2

Sensitivity index: We referred to Eriksen et al. (2005) to define sensitivity as the degree to which agricultural productivity (maize yield) is affected either adversely or beneficially by the rainfall or temperature variability (exposure). Long term changes in maize yields were used to represent agricultural sensitivity because maize is the staple food grown in all the 47 counties of Kenya (Kenya National Beureau of Statistics, 2007). Maize is a source of food, income and employment for the majority of Kenyans who practice farming as the main livelihood activity (Nkako. M et al. 2005; Kenya National Beureau of statistics 2011). Maize productivity thus has a knock effect on a range of livelihood assets including financial (income), human (employment) and health (food and nutrition). The focus on maize also allowed for the calculation of sensitivity indices for all the 47 counties and this would not be possible with other crops which are only cultivated in specific counties. Yearly maize yield data for a period of 38 years (1975- 2012) was obtained from the Kenya's Ministry of Agriculture, Project Monitoring Unit. The data obtained had some missing values and so we undertook an extensive review of yearly district agricultural reports for each of the Kenyan counties to fill in the gaps and to validate the acquired data. The maize yields were first detrended to remove any yield changes attributable to non-climatic factors such as technological development (Lobell et al. 2007). Detrending was achieved through simple calculation of linear trends (Easterling et al., 1996). Linear trends provide better balance between yield prediction and simplicity (Chatfield 1996). In this detrending, the observed yield was plotted against the respective years in a time series. A linear trend was fitted on the plot, and the equation of this linear trend was used to calculate the expected yields. Resulting differences in the observed and expected yield were interpreted as residual and attributed to technology. The sensitivity index was derived from the ration of expected to observed yields (Simelton et al. 2009; eq. 3).

Sensitivity index = expected yield (tons/ha)/actual yield (tons/ha).........................eq. 3

Adaptive capacity index: Adaptive capacity here refers to the ability of a system or community to moderate the effects of climate change (exposure index) on agricultural productivity (sensitivity index). Adaptive capacity is facilitated by the asset bases making up the sustainable livelihood framework (Gbetibouo et al. 2010). The assets are categorized into natural capital (land area, land productivity etc.), financial capital (poverty levels, per capita income etc.) human capital (employment, literacy rate, health etc.), physical capital (infrastructure) and social assets (governance, social networks etc.). The assets are owned and used by households, communities or governments for daily living and as safety nets during shocks such as climatic exposures (Scoones, 1998). In calculating adaptive capacity, incorporating indicators from the five livelihood capitals reportedly makes a study more comprehensive with the desired analytical rigor (Challinor et al., 2007). On the other hand, an appropriate level of indicators reduces complexity and limits large errors associated with parameterizations (Challinor et al. 2007). Nonetheless, lack of long terms socioeconomic data often limits comprehensive assessments of adaptive capacity especially for sub-Saharan African countries (Vincent 2007). Similar data limitation was experienced in this study and so we adopted a simplified approach used for Ghana in Antwi-Agyei et al. (2012; eq. 1) in which adaptive capacity is calculated from poverty and literacy rates. Poverty rates reportedly reflect a wide range of socio-economic factors including income sources, earnings, expenditure, amongst others (Ravallion et al. 2009). Data on literacy and poverty rates were obtained from the 2005/2006 Kenya National Household Budget Survey (Kenya National Beureau of Statistics 2007) and the 2009 national population and household census (Republic of Kenya 2009). The two years for which the data was available fall within the vulnerability indexing period.

Adaptive capacity index= (Literacy rate/100) + (100- poverty rate)/100)............eq. 4

The overall vulnerability for each county was calculated using equation 5.

Overall vulnerability = Exposure index + Sensitivity index – Adaptive Capacity index... eq. 5

The county vulnerabilities were averaged into regional/provincial vulnerability indices. SPSS was used to perform hierarchical cluster analysis to group the

counties into ‘low’ ‘medium’ and ‘high’ vulnerability. ArcGIS was used to overlay the categorised indices on the county map to generate a vulnerability map for Kenya.

Step 2: Locating REDD projects on the vulnerability map

An inventory of REDD projects occurring in various parts of Kenya was undertaken. Projects operating under various standards including Voluntary Carbon Standard (VCS), Climate Community and Biodiversity Standard (CCBS), Plan vivo, and the Chicago Climate Exchange were considered in the inventory. As clarified in the introduction, both forestry and agro-forestry projects (e.g. climate smart agriculture projects) were included in the inventory with the assumption that all these projects posit lessons for the expected national REDD. We also considered existing and upcoming (pipeline) projects because both are indicative of the spatial flow of carbon investments currently and in the future. Table 1 shows the kind of information gathered about the projects.

Table 1: Attributes considered in the REDD project inventory and corresponding data sources

Project attribute	Data source
a. Project type and existence	➢ Global databases: CIFOR’s global REDD map found at http://www.forestclimatechange.org/redd-map/, Climate Community and Biodiversity Standard (CCBS) ➢ REDD inventory report: Ecosystem market place state of forestry carbon report 2013. ➢ Field visits to selected project sites in Kenya
b. Project geographical location	➢ Project design document ➢ Google earth application
c. Forest type	➢ Project design documents ➢ Vegetation map of Kenya
d. Project validation standards	➢ Project design document
e. Project design objectives	➢ Project design document
f. Project stakeholders	➢ Project design document ➢ Interview with project staff

The projects' information including location and type were digitized and overlaid on the vulnerability map using ArcGIS map application to show how the nature and type of REDD project vary with vulnerability. The difference in the distribution of the projects across the three clusters of vulnerability was further tested statistically using one-way ANOVA.

Step 3: Characterizing the REDD -vulnerability linkage

We explored the socioeconomic characteristics that may significantly influence the spatial targeting for REDD projects. Based on the statistically significant correlation between the distribution of REDD projects and the county vulnerability indices, we assumed a causal relationship in which a range of socio-economic characteristics significant to the vulnerability indices were interpreted as factors influencing the spatial attractiveness or unattractiveness to REDD projects subject to expert consultations. Pearson correlation was performed between seventeen (17) socioeconomic indicators, representing the five livelihood capitals (natural, financial, human, physical and social; Table 2) and the respective county vulnerability indices. Socioeconomic data were obtained from the National Household Budget Survey of 2005/2006 (Kenya National Beureau of Statistics 2007) and the 2011 Kenya Statistical abstracts (Kenya National Beureau of statistics, 2011). The indicators were selected based on a scoping fieldwork (Atela 2013) and were standardised into percentage (0-100) in order to achieve normalised weights (Gbetibouo et al., 2010). Experts from the UNFCCC (n=2), national REDD staff (n=2) and staff of a forestry project (the Kasigau Corridor REDD project) and an agroforestry project (the Kenya agricultural carbon project) (n=8) were consulted to clarify the resulting REDD – vulnerability linkages.

Table 2: Socioeconomic characteristics (explanatory indicators)

Asset base	Livelihood indicator
Natural assets	Agricultural land holding (acres)
	Proportion of households with land titles
	Proportion of area under forest (acres)
Financial assets	Proportion of households with non-farm income sources
	Proportion of households with better access to non-farm credit
Human assets	Child immunization rate
	Unemployment index
	Literacy rates
Physical assets	Proportion of households accessing public primary school at 5km or more
	Time taken to access drinking water (>1hr)
	Proportion of households accessing health facility at 5km or more
	Proportion of households with access to daily market at 5km or more
	Proportion of households accessing tarmac or asphalt road at 5km or more
	Proportion of households with access to a post office at 5km or more
Social assets	Proportion of households totally affected by shocks
	Proportion of households perceiving rampant corruption among civil servants
	Percent contribution to national poverty
	Proportion of households feeling unsafe

3 Results

The results are presented in correspondence with the respective objectives. The first part presents the vulnerability index map for Kenya while the distribution of REDD projects on the index map is shown in the second part. The third and fourth parts characterise the socioeconomic features of vulnerability that could be influencing the location of REDD projects.

3.1. Vulnerability index map for Kenya and the distribution of REDD projects

Figure 1 shows the hierarchical clustering of the calculated vulnerability indices. Counties clustered as 'low' have a mean index of 0.766, while counties clustered as 'medium' and 'high' have a mean index of 1.615, and 2.429 respectively. The cluster

means were significant at p=0.000. Discriminant analysis of the clustering confirmed 98% correct clustering.

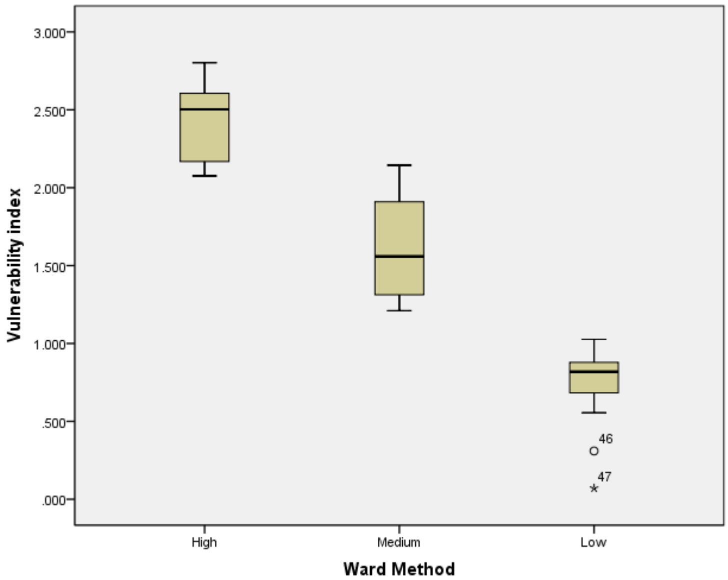

Figure 1: Hierarchical clustering of vulnerability indices of 47 counties. The 46th and 47th counties are Meru and Nairobi respectively and were outliers in the clustering.

Correlation coefficients show that precipitation changes within the maize growing period accounted for about 54.8% ($p<0.05$) of changes in maize yields (sensitivity indices). This was higher compared to the influence of temperature which accounted for 43.2% ($p<0.05$). A field study recently reported that drought-resulting from rainfall variability is the most crucial impact of climate change compared to fire, windstorms, pests and diseases (Nkem et al. 2012). The significance of precipitation to yield sensitivity nonetheless varied across the high (69.8%), medium (52.1%) and low (48.4%) vulnerability clusters. The variation in precipitation (exposure index) was not significantly different between the clusters ($p=0.06$) even though the same counties had significantly different sensitivity ($p<0.05$) and vulnerability indices ($p<0.01$). County adaptive capacity indices were highly significant to the changes in maize sensitivity (0.768; ($p<0.01$).

The resulting vulnerability indices show that 8 of the 47 counties (17.02%) were clustered as high, 11 counties (23.41%) as medium and 28 counties (59.57%) as low vulnerability (Fig 2). Figure 2 illustrates the distribution of REDD projects across sub-national vulnerability clusters of Kenya. The North Eastern province had the highest proportion (100%) of counties in the high vulnerability category while Central, Nairobi

and Nyanza provinces had no county in the high vulnerability cluster. Two counties (Marsabit and Isiolo) constituting 25% of the counties in the Eastern province were clustered under high vulnerability while Samburu and Turukana counties constituting 14.3% of the counties in Rift valley were clustered under high vulnerability. One county in the Coast province (Tana River) was clustered under high vulnerability. Coast province had the highest proportion of counties (50%) in the medium vulnerability cluster compared to other provinces. The average national vulnerability index is 1.19 and this belongs to the 'medium' cluster.

The figure 2 further illustrates that a total of 15 projects were inventoried, 10 (66.7%) REDD_ agroforestry and 5 (33.3%) REDD pure forestry projects. Majority of the projects (86.7%) were located in counties with low vulnerability indices while the rest were found in counties with medium vulnerability cluster. No project was found in counties with high vulnerability indices. All the REDD _agroforestry projects were located in low-vulnerability counties while 3 (60%) and 2 (40%) of the REDD _pure forestry were located in the low and medium vulnerability clusters respectively. The number of projects across the vulnerability indices were significantly different ($p<0.05$).

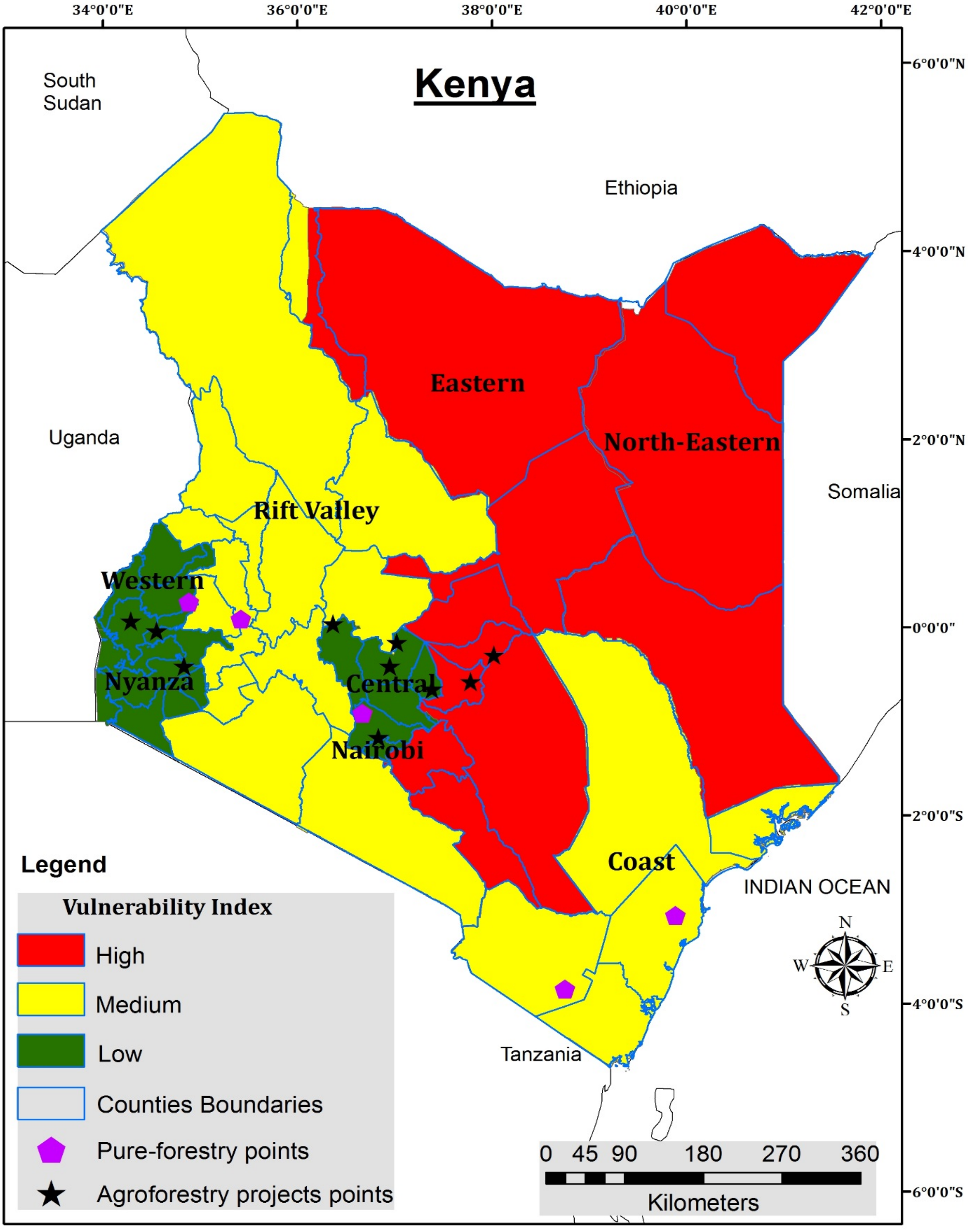

Figure 2: Spatial distribution of REDD projects across demarcated provincial/regional vulnerability indices

3.2. Evaluating projects' designs in various vulnerability contexts

In terms of project standard, majority of the projects (66.7%) operate under the VCS standard even though only 3 of the VCS projects (30%) had received VCS approval. There was no significant correlation between project standards and vulnerability indices. There was also no significant difference in project standards in relation to project type. Majority of both REDD _pure forestry projects and REDD _agroforestry projects operated under the VCS standard.

Reforestation, emission reduction and sustainable livelihoods were cited in all the projects' documents as main project objectives (Fig 3). There was no significant difference between project objective and vulnerability clusters within which the projects occur. However, a paired sample t-test subjecting counts of projects objectives against project type revealed that the objectives of both REDD_ pure forestry and REDD_ agroforestry were statistically similar on emission reduction ($p<0.23$), sustainable livelihoods ($p<0.23$) and reforestation ($p<0.23$). The t-test nonetheless revealed statistical differences in the objectives related to improved agricultural productivity which was explicit for REDD_ agroforestry projects ($p<0.05$) and biodiversity protection which was explicit for REDD _ pure forestry projects ($p<0.05$).

In terms of the forest/ tree types being conserved for carbon, majority of projects (73.3%) aim to protect or conserve humid forests/trees all of which occur in the low-vulnerability cluster. Only one project (6.3%) aims to conserve dry-land forest and this occurs in the medium vulnerability cluster. Two projects, the Kenya smallholder coffee project (low-vulnerability area) and the tree flights (medium-vulnerability area) have established/protect perennial cash crops of coffee and cashew nuts plantations respectively (Fig 4). The number of projects targeting humid forests was significantly higher than those targeting other forest types ($p<0.01$).

In terms of project stakeholders, the international community including international NGOs/consulting companies, international private companies and multilateral funding agencies are the proponents/funders for over 75% of the projects (Fig 6). The local communities, national governments and national NGOs are proponents or funders to less than 20% of either REDD _agroforestry of REDD_ pure forestry

projects. There was no relationship between project stakeholders and the vulnerability clusters where the projects occur.

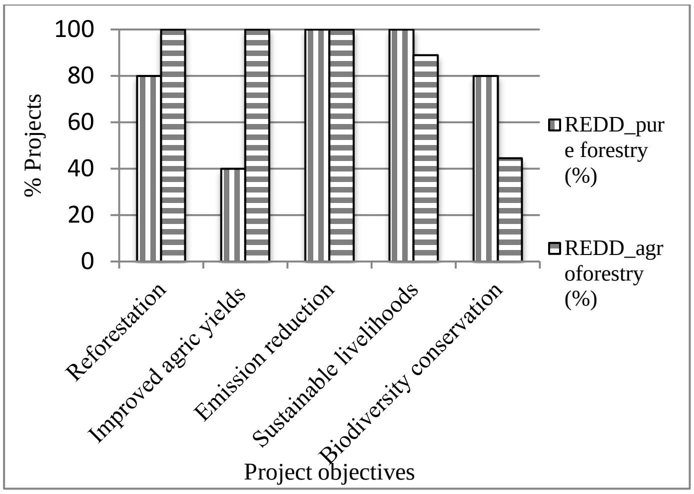

Figure 2: Project objectives by type

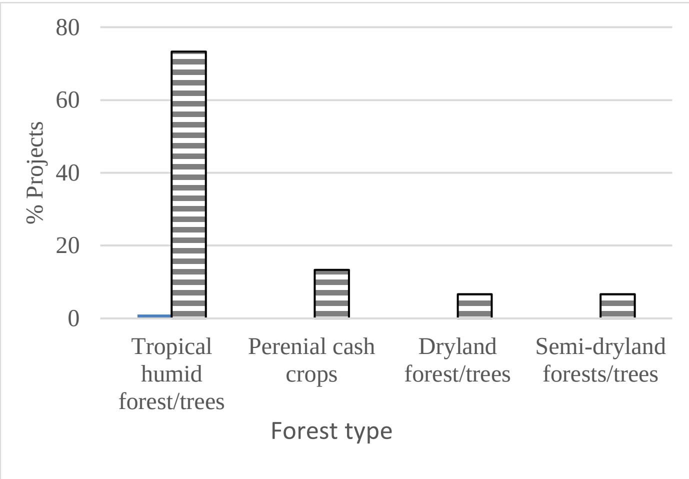

Figure 3: Forest/tree type protected/conserved

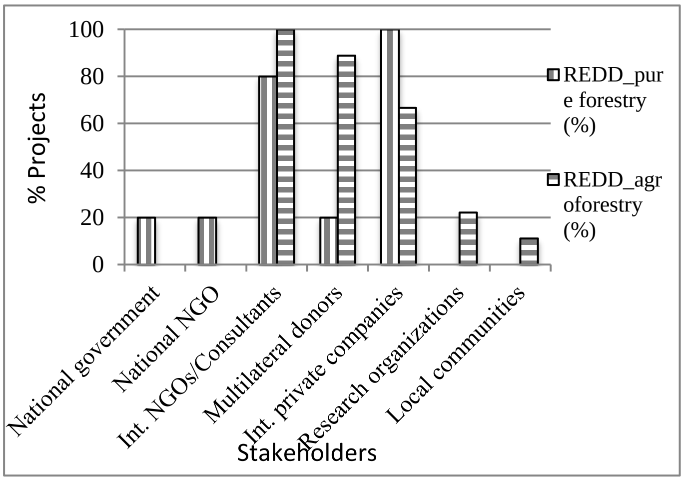

Figure 4: Project stakeholders by type

3.3. Exploring the causal relationship between vulnerability and spatial targeting of REDD projects in Kenya.

We further explored the socioeconomic characteristics that may significantly define the vulnerability – REDD relationship. Table 3 shows the list of indicators and their respective causal significance to REDD projects.

Table 3: Correlation co-efficient for various explanatory attributes determining vulnerability and subsequent carbon investments in Kenya

Asset base	Indicator (%)	Coefficient to vulnerability	Causal significance to REDD projects
Natural assets	Agricultural land holding (acres)	.181	.181
	Proportion of household with land titles	-.552**	.552**
	Proportion of area under forest	-.728**	.728**
Finance	Proportion of household with non-farm income sources	-0.226	.226
Human capital	Proportion of households with employment	-.346*	.346*
	Literacy rates	-.407**	.407**
	Unemployment index	-.014	.014
Physical assets	Proportion of household accessing public primary school at >5km (bad)	.199*	-.199*
	Proportion of households taking >1hr to access drinking water (bad)	.475**	-.475**
	Proportion of household accessing health facility at >5km (bad)	.367*	-.367*
	Proportion of household with access to daily market at >5km	.476**	-.476**
	Proportion of household accessing tarmac/asphalt road at >5km	.354*	.-354*
	Proportion of household with access to a post office at > 5km	.403**	-.403**
Social assets	Proportion of household totally affected by shocks	.436**	-.436**
	Population density	-.369*	.369*
	Percent contribution to national poverty	.243	-.243
	Proportion of household feeling unsafe	.063	-.063

2 tailed Pearson correlation test *significant at 0.05 **significant at 0.01

Within the natural capital, forest cover showed the strongest causal influence on project location (-0.728 at p<0.01). Less vulnerable counties with more projects have a greater proportion of their land under forest cover. Findings further show that counties where greater proportion of households were in possession of legal titles to land and are less vulnerable (p<0.01), host more projects. Within the financial capital, non- farm income did not show any significant causal relationship with

projects locations. Employment and literacy rates were the main human capitals that had causally significant implications on the location of REDD projects. Infrastructure/physical capital and particularly access to water, access to market, access to road and post office significantly have a causal effect on the location of the projects ($p<0.05$). In terms of social assets, counties which are more sensitive to shocks and more vulnerable are less attractive to REDD projects ($p<0.01$). Ranking the level of significance of these assets, forest cover, land tenure, water access and market access, literacy rates and sensitivity to shocks are the top five assets having causal implications on the location of carbon projects.

3.4. Expert opinion

Experts, both from the UNFCCC and state REDD domain were interviewed to elaborate on the observed patterns in REDD spatial targeting and vulnerability indicators. The experts concurred that even though poverty alleviation and emission reduction are key official criteria in the spatial targeting of REDD projects, additional factors such as donor and proponent interests often take precedence in locating REDD demonstration projects. The staff stated that currently, most demonstration projects are being implemented and funded largely by private for-profit companies and that investments certainty is key to these companies. Some of the socioeconomic indicators such as forest resource cover, secure land tenure and infrastructural assets such as good roads and market access serve to reduce transaction costs for most profit seeking project proponents, argues the staff. Accordingly, the interests of the private sector in locating REDD funds remain superior currently due to their de-facto financial power. The UNFCCC staff in charge of national communications concurred that whereas adequate affirmative measures are in place to promote global equality in carbon investments through REDD support funds directed to developing countries, little has been done to address potential intra-state inequality in the flow of REDD funds. The experts suggested that the national REDD policy making process should be responsible for ensuring equity in access to carbon investments at sub-national level.

However, consultation with the Kenya National REDD Secretariat, indicated that the current national readiness plan largely focuses on conserving humid forests known as water towers that occur in low vulnerable areas. An expert at the Secretariat mentioned that the current national policy making process draws much of its content

from the World Bank FCPF guidelines which is funding the process. The FCPF process has provisions for local safeguards and community participation but does not emphasise sub-national equity issues in the distributing of REDD investments, argued the expert. Experts from both national and global domains emphasised that research highlighting intra-state equality in REDD investments would help inform and influence the REDD process not only at the national level but would also be useful for multilateral actors supporting REDD institutional development in specific developing counties. The projects' staff also agreed that the socioeconomic indicators are crucial to project proponents and added that most of the current REDD project developers have had prior work with integrated conservation and development projects and often target to initiate REDD in areas where such projects existed because of the existing engagement platform that reduces costs.

4 Discussion

4.1. Contextualizing the vulnerability index map

This study relates REDD projects to vulnerability indices of various counties of Kenya. The vulnerability index map for Kenya was developed based on the IPCC conceptualization of vulnerability as a function of exposure, sensitivity and adaptive capacity. Exposure and sensitivity and adaptive indices were generated from reasonably long term precipitation, maize yield and socioeconomic data. Statistical test indicate that precipitation accounted for relatively significant proportion of maize yield changes than temperature and thus was a better climate variable for vulnerability indexing. However, in calculating adaptive capacity index, only two socioeconomic indicators were applied due to data limitations. Adaptive capacity is a function of many socio-economic indicators, spanning across the five livelihood capitals (Vincent 2007). It is possible that the calculated adaptive capacity indices could change if more variables were included in the calculation and this could subsequently change the vulnerability pattern. Further, the socio-economic indicators of poverty and literacy rates were available only for two years (2006 and 2009) and so the resulting indices were based on the assumption that the indicators were not significantly different in the other years and that in any case, changes in the indicators would remain proportional for all the counties. The resulting adaptive

capacity indices were nonetheless significantly correlated to changes in maize yields implying the indicators considered have significant control over sensitivity of crop yields to rainfall perturbations. Due to these data limitations, the resulting vulnerability index map should be interpreted in relative rather than absolute terms and has been used here as a framework for indicating the flow of REDD funds across relative sub-national socio-economic conditions within Kenya. Of the three indices, adaptive capacity encompassing poverty and literacy rates, had the greatest influence on vulnerability. Studies (IPCC 2007; Adger et al. 2003) show that underlying adaptive capacity is key in buffering systems or communities from climatic shocks.

4.2. Linking vulnerability to the spatial locations of REDD projects

REDD (and other carbon projects), at the global policy level, is supported as a cost effective policy programme that could form part of adaptive strategy for vulnerable areas (Beymer-Farris and Bassett 2012) and enhance climate justice by directing funds to communities affected most by climate change. However, this study reveals a more complex situation in practice, one in which a complex mix of REDD investors and funders are keen to avoid initiating projects in relatively low vulnerable areas, largely based on business interests.

During COP 16 (UNFCCC, 2010; decision 1/CP.16), the Ad hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA) recommended a variety of funding possibilities including public, private and market based funds for REDD and these were which were encouraged to support REDD demonstration activities. While international donors such as the World Bank FCPF are concentrating on supporting REDD institutions in Kenya (and elsewhere), more than three-quarters of REDD demonstration projects in the country are currently funded and managed through international private and consulting companies with the objective of making profits out of the projects. Internationally accepted emission verification rules were recommended during COP 17 in Durban and these rules emphasize performance as key criteria for projects to qualify for payments. The for-profit proponents of REDD demonstrations may therefore be keen in reducing financial risks and performance failures associated with relatively vulnerable conditions. Proponents of the early REDD demonstrations are reportedly careful to minimise investment risks by avoiding controversies and unrealistic expectations that

could emerge when projects are located in poorly developed systems (Sills et al. 2009). Even though this business interest was not explicit in the project design documents we reviewed, it is arguably crucial in locating REDD demonstration projects according to the experts we consulted. A number socioeconomic indicators discussed below were found to be potentially responsible for influencing investors interests in locating REDD projects in low vulnerable areas.

4.3. Socio-economic factors explaining REDD - vulnerability linkages

This study further reveals specific socioeconomic indicators of vulnerability that could be responsible for influencing investors' interest to locate projects in particular areas. Based on this study, such features include but are not limited to; forest cover (natural capital), access to water (physical capital), literacy rates (human capital), secure land tenure, low sensitivity to shocks, and access to markets (social capital).

Forest cover is directly related to carbon stock density that determines the amount of carbon credit deliverable for payment. Most projects' proponents may therefore prefer to generate higher revenues by locating activities in areas with higher forest cover. Studies on the spatial targeting for REDD in Tanzania (Lin et al. 2014) and East Kalimantan Indonesia (Harris et al. 2008), revealed that forest carbon stocks is a priority criteria for choosing areas for REDD project. It is argued that locating projects in areas with higher forest carbon stocks could enhance efficiency in REDD because such areas could enhance other ecosystem services that support local livelihoods and reduces vulnerability (Engel et al. 2009).

Forest carbon stock is not only a function of forest cover, but is also dependent on forest types. Various forest types that exist in Kenya, ranging from tropical humid forests to dry-land savannah forests, are recognized under REDD as long as they meet the definitional criteria of canopy cover. However, this study shows that more than three-quarters of the inventoried projects seek to protect patches of tropical humid forests/trees occurring in low vulnerable areas of Mt Kenya, Rift valley and western highlands while ignoring the wider dry-land ecosystems that constitute over 75% of Kenya's vegetation cover. Only one project, 'the Kasigau Corridor REDD project', targeted a dry-land ecosystem in the Taita-Taveta County (medium-vulnerability), Coast province while other parts of the Coast, Lower Eastern and North Eastern provinces dominated by dry-land vegetation had no project targeting

or attempting a feasibility evaluation there. Dry-land ecosystems/forests reportedly store low amount of carbon stocks (0.05–0.7 t//ha/year) compared to the tropical humid forests that sequester 5.9 t C/ha/year (Perez et al. 2007; Gibbz, et al. 2007). Therefore, investing in dry-land ecosystem may not be attractive for the profit seeking investors currently dominating REDD demonstrations. On the contrary, experiences of the Kasigau project revealed that delivering carbon credits from a dry-land ecosystem provides low opportunity costs to the project thereby enhancing project's acceptance locally as a better alternative economic use for the land (Atela 2013). Research that explores such opportunities within dry-land could motivate and inform REDD investments in such vulnerable ecosystems.

Land tenure in REDD has attracted significant academic and political debates with mixed opinions about what tenure system may work well for the programme. In this study, areas where larger proportion of households own land titles hosted more REDD+ projects. It has been argued that informal rights to land with no legal proof, as is in most vulnerable areas, may not enable legally enforceable and credible commitment to deliver carbon offsets (Chhatre et et al. 2012)). Informal land rights may be more unfavourable in projects where community members themselves are the service providers, argues Gutman (2003). Weak land tenure has been touted as a key governance issue that sometimes overcomes mitigation potential as a site selection criterion thus keeping away REDD investments in some areas (Chhatre et al. 2012; Jindal et al. 2008). However, the debate about land tenure still remains elusive in light of contextual suitability and existing local systems. For instance, while secure land tenure has largely been interpreted to mean private/individualised land tenure, and has been supported to be key to REDD performance and security of investments (Chhatre et al. 2012), certain cases such as the Kasigau project (REDD_ pure forestry) have shown apparent success through communal land tenure systems as a framework for community participation and more inclusive benefit sharing (Atela 2013). Another case project 'the Kenya Agricultural Carbon Project' (REDD _agroforestry) in western Kenya, works with farmers who largely hold customary land rights as individual families but communal use of the land is a common practice (Atela 2012). This raises questions on whether farmers should allow free grazing of land during the dry season or instead conserve residues for sequestration and individual benefit. Such mix of land and resource tenure arrangements may be overlooked as the commoditisation of carbon creates

incentives to privatise and individualise land potentially locking out landless, tenant farmers and even women and youth (with no traditional land inheritance rights) from access and ownership of land resources. These two cases serve to indicate that the debate about land tenure in REDD should not be confined to individualised titles but should be broadened to reflect the contextual suitability of different tenure systems including customary rights.

Good access to water also showed significance to the spatial targeting of REDD projects. Counties with good access to water resources hosted more projects. Counties in North Eastern and Lower Eastern Kenya experience water scarcity with annual rainfall less than 400 mm p.a. Such areas may not be attractive to REDD projects because they might not support projects' objective of reforestation for carbon (Zomer et al. 2006). Additionally, water scarcity can be a challenge to REDD projects both in terms of generating carbon credits and participation time in carbon activities. For example, the Kenya Agricultural Carbon Project works with groups of farmers with women as the main members. Water scarcity, during dry periods, however, means that the women have to spend more time searching for water instead of implementing sustainable land management practices for carbon. In the Kasigau case where water scarcity is severe, the project has allocated part of the carbon proceeds to communal water projects and this has yielded an apparently uncontested acceptance of the project mainly because the local people perceive it to be more sensitive to local vulnerabilities relative to other state interventions. The Kasigau situation shows that if projects are located in vulnerable areas, with mitigation potential, impacts may be more explicit for the local people compared to high potential areas with better economic alternatives relative to REDD. This also means that pro-poor targeting for REDD could spur greater synergies between mitigation and adaptation.

Other factors such as market access also showed significance for areas attractive to REDD projects. Areas with closer proximity to Kenya's economic hubs such as Nairobi, Nakuru, Kisumu, Eldoret and Kakamega access better markets for their agricultural produce at better prices. This effectively translates to better income, reduced poverty and reduced overexploitation of natural resources including forests and soil nutrients. Literacy rates have been factored in the vulnerability calculation and have shown significance to locating REDD projects in Kenya. According to

Brown et al. (2011), REDD projects prefer to keep transaction costs low and would avoid areas with high illiteracy and poverty rates because such areas require additional investments in capacity building. Sensitivity to shocks was also a significant factor in locating REDD and this also was already reflected in the vulnerability indices generated.

The discussion above reflects vulnerability features crucial for locating REDD projects based on statistical test performed on secondary data. However, staff interviews within the two projects cited earlier, strongly pointed to the crucial role of prior experience with past conservation projects in locating REDD projects. For instance the Kenya Agricultural Carbon Project is among the first REDD _agroforestry issuing credits under VCS and was developed from over 20 year experience with local farmers in agroforestry related activities. Similarly, the Kasigau project, Africa's first REDD project to issue VCS credits, has had more than a decade engagement in the local area for wildlife conservation and eco-tourism. Studies show that past experiences in particular areas provides a platform for REDD implementation by using established local networks and organization thereby reducing costs and time of inventing new engagement networks in other places (Blom et al. 2010). Sills et al. (2009) concur that existing relationships with local and national stakeholders provide favourable and low-risk institutional settings for REDD proponents. The role of past intervention in ensuring the success of REDD in practice is not covered in this study but should be an important area of research.

5 Conclusions: policy implications

This study focuses on Kenya as a case study to assess the spatial location of REDD projects across sub-national level vulnerability indices. Findings indicate that majority of REDD projects in Kenya are hosted in relatively low vulnerable areas where inherent socioeconomic conditions are deemed favourable to the interests of project proponents. The findings coincide with the experiences under the Kyoto-based CDM in which vulnerable areas were technically excluded from accessing carbon funds. Yet the UNFCCC debates on REDD have, over time, coined a generic notion that REDD is pro-poor simply because it targets developing countries. The Kenyan case shows that actors endowed with financial resources draw from the UNFCCC negotiation outcomes to usefully showcase REDD in 'developing countries'.

However, beyond the ‘developing country’ tag, business interest ensues, conflicting with the pro-poor notion of a ‘global REDD’ and, in this case, seem to deny relatively vulnerable communities with mitigation potential a chance to participate and benefit from REDD funds.

In the discussion, we have highlighted the influence of assets in locating REDD projects. We have also acknowledged the ease of doing REDD business in less-vulnerability areas. However, we have highlighted the fact that medium-high-vulnerability areas, with mitigation potential, may present some opportunities for REDD in terms of enhanced recognition of impact, low opportunity costs and greater local acceptance of projects thereby promoting greater synergies between mitigation and adaptation. Such opportunities might be realised if REDD adopts a pro-active approach to implementation. In this pro-active approach, REDD should not only target to benefit from existing well developed systems but should also aim to streamline resource governance in vulnerable communities. This could be achieved through enabling policy framework that supports pro-active and pro-poor REDD funding and design rules. Pro-active design rules could usefully reduce opportunistic considerations in locating REDD projects.

The UNFCCC has institutionalised steps to safeguard the interests of local communities at all stages of REDD. However, little has been done to institutionalise equity in the distribution of REDD investments/projects within particular developing countries. UNFCCC experts pointed to the national REDD policy process as an avenue where equity in distributing REDD investments could be realised. However, an analysis of REDD readiness plans for Kenya, supported by the World Bank FCPF, reveals that the country’s REDD readiness plan is skewed towards conserving the humid forests or ‘water towers’ and barely mentions dry-land forests/vegetation where relatively high-vulnerability communities in Kenya live. The readiness plan is also subject to World Bank FCPF terms that must be met for the country to qualify for subsequent implementation funds. These World Bank’s terms of reference however lay more emphasis on the safeguards rather than equity in spatial fund/projects allocation.

Finally, the role of science in unveiling the opportunities associated with locating REDD in vulnerable communities is paramount. While science has successfully informed the UNFCCC negotiations on the local rights in REDD, very few studies

have attempted to generate knowledge on equity in access to REDD investments/projects in practice. The REDD policy process has therefore confined social justice to community consultation and benefit sharing but has virtually neglected issues of spatial equality in REDD investments as a pertinent component of social justice. Additional research, that analyses the practical unfolding of specific projects in relatively vulnerable settings, could unveil lessons for policy makers and project proponents to consider in directing REDD investments to such areas. Emerging concepts such as reducing emission from all land uses (REALU) and the landscape approach, if explored further, could also provide opportunities for vulnerable communities to access REDD funds/projects and provide a framework for enhanced synergies between mitigation and adaptation.

6 Acknowledgements

The study was funded by the International Research Scholarship of the University of Leeds, the Africa College based at the University of Leeds and the ASB-Partnerships for the Tropical Forest Margins. Professor Piers Forster provided insightful comments and guidance in designing and writing this paper.

7 References

ADGER, W., ARNELL, N. & TOMPKINS, E. (2005) Successful adaptation to climate change across scales. *Global Environmental Change-Human and Policy Dimensions* 15, 77–86.

ADGER, W.N. 2003.Social aspects of adaptive capacity. Smith J., Klein, R., Huq, S. (Eds). Climate Change, Adaptive Capacityand Development, Imperial College Press, London.

ANGELSEN, A., BROCKHAUS, M., KANNINEN, M., SILLS, E., SUNDERLIN, W. D. & WERTZ-KANOUNNIKOFF, S. (2009) *Realising REDD+: National strategy and policy options. CIFOR, Bogor, Indonesia,* Bogor, Indonesia., CIFOR.

ANTWI-AGYEI, P., FRASER, E. D. G., DOUGILL, A. J., STRINGER, L. C. & SIMELTON, E. (2012) Mapping the vulnerability of crop production to drought in Ghana using rainfall, yield and socioeconomic data. *Applied Geography,* 32**,** 324-334.

ATELA, J. (2012) The Politics of Agricultural Carbon Finance: The Case of the Kenya Agricultural Carbon Project. STEPS Working Paper 49, Brighton: STEPS Centre.

ATELA, J., DENICH, M., KAGUAMBA, R. & KIBWAGE, J. (2012) Agricultural land allocation in small farms around Maasai Mau forest, Kenya and the implications on carbon stocks. *Journal of Ecology and the Natural Environment* 4**,** 98-108.

BARRIOS, S., OUATTARA, B. & STROBL, E. (2008a) The impact of climatic change on agricultural production: Is it different for Africa? *Food Policy,* 33**,** 287–298.

BARRIOS, S., OUATTARA, B. & STROBL, E. (2008b) The impact of climatic change on agricultural production: Is it different for Africa? *Food Policy,* 33**,** 287-298.

BEYMER-FARRIS, B. A. & BASSETT, T. J. (2012) The REDD menace: Resurgent protectionism in Tanzania's mangrove forests. *Global Environmental Change,* 22**,** 332-341.
BLOM, B., SUNDERLAND, T. & MURDIYARSO, D. (2010) Getting REDD to work locally: lessons learned from integrated conservation and development projects. *Environmental Science & Policy,* 13**,** 164-172.
BOND, I., GRIEG-GRAN, M., WERTZ-KANOUNNIKOFF, S., HAZLEWOOD, P., WUNDER, S. & ANGELSEN, A. (2009) Incentives to sustain forest ecosystem services: A review and lessons for REDD Natural Resource Issues No. 16. International Institute for Environment and Development, London, UK, with CIFOR, Bogor, Indonesia, and World Resources Institute, Washington D.C., USA
BROOKS, N., ADGER, W. & KELLY, P. (2005) The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. . *Global Environment Change* 15**,** 151-163.
CAPOOR, K. & AMBROSI, P. (2006) State and Trends of the Carbon Market 2006: A focus on Africa. World Bank, Washington DC.
CERBU, G. A., SWALLOW, B. M. & THOMPSON, D. Y. (2011) Locating REDD: A global survey and analysis of REDD readiness and demonstration activities. *Environmental Science & Policy,* 14**,** 168-180.
CHALLINOR, A., SIMELTON, E., FRASER, E., HEMMING, D. & COLLINS, M. (2010) Increased crop failure due to climate change: assessing adaptation options using models and socio-economic data for wheat in China. . *Environmental Research Letters,* 5**,** 034012 (8pp).
CHALLINOR, A., WHEELER, T., GARFORTH, C., CRAUFURD, P. & KASSAM, A. (2007) Assessing the vulnerability of food crop systems in Africa to climate change. *Climatic Change,* 83**,** 381-399.
CHATFIELD, C. (1996) *The analysis of time series,* CRC Press, Boca Raton, FL, 283.
CHHATRE, A., LAKHANPAL, S., LARSON, A. M., NELSON, F., OJHA, H. & RAO, J. (2012) Social safeguards and co-benefits in REDD+: a review of the adjacent possible. *Current Opinion in Environmental Sustainability,* 4**,** 654-660.
DIAZ, D., HAMILTON, K. & JOHNSON, E. (2011) Status of forest carbon markets 2011. Ecosystem Market Place.
EAKIN, H. & LUERS, A. (2006) ASSESSING THE VULNERABILITY OF SOCIAL - ENVIRONMENTAL SYSTEMS. *Annu. Rev. Environ. Resour. ,* 31**,** 365–394.
EASTERLING, W., CHEN, X., HAYS, C., BRANDLE, J. & ZHANG, H. (1996) Improving the validation of model-simulated crop yield response to climate change: an application to the EPIC model. *Climate Research,* 06**,** 263-273.
ENGEL, S., WUNSCHER, T. & WUNDER, S. (2009) Increasing the efficiency of forest conservation: the case of payments for environmental services in Costa Rica IN PALMER, C. & ENGEL, S. (Eds.) *Avoided Deforestation: Prospects for Mitigating Climate Change.* New York, NY, Routledge.
ERICKSEN, P., THORNTON, P., NOTENBAERT, A., CRAMER, L., JONES, P. & HERRERO, M. (2011) Mapping hotspots of climate change and food insecurity in the global tropics. CCAFS Report 5. Copenhagen, Denmark: CCAFS. .
ERIKSEN, S. H. & KELLY, P. M. (2007) Developing Credible Vulnerability Indicators for Climate Adaptation Policy Assessment. *Mitigation and Adaptation Strategies for Global Change,* 12**,** 495-524.
FALKENMARK, M. & ROCKSTRÖM, J. (2008) Building resilience to drought in desertification-prone savannas in Sub-Saharan Africa: The water perspective. *Natural Resources Forum,* 32**,** 93-102.
FAO (2010) Global Forest Resources Assessments. Rome, FAO.
FCPF, FIP & UN-REDD (2010) Enhancing Cooperation and Coherence among Multilateral REDD+ Institutions to Support REDD+ Activities. . Washington D.C, Climate Investment Funds, FCPF, UN-REDD Program

FORSTER, P., JACKSON, L., LORENZ, S., SIMELTON, E. & BAHADUR, K. (2012) Food Security: Near future projections of the impact of drought in Africa *Centre for Low Carbon Futures*

FRASER, E. D. G., SIMELTON, E., TERMANSEN, M., GOSLING, S. N. & SOUTH, A. (2013) “Vulnerability hotspots”: Integrating socio-economic and hydrological models to identify where cereal production may decline in the future due to climate change induced drought. *Agricultural and Forest Meteorology,* 170**,** 195-205.

FÜSSEL, H.-M. & KLEIN, R. T. (2006) Climate Change Vulnerability Assessments: An Evolution of Conceptual Thinking. *Climatic Change,* 75**,** 301-329.

GBETIBOUO, G. A., RINGLER, C. & HASSAN, R. (2010) Vulnerability of the South African farming sector to climate change and variability: An indicator approach. *Natural Resources Forum,* 34**,** 175-187.

GIBBS, H., BROWN, S., NILES, J. & FOLEY, J. (2007) Monitoring and estimating tropical forest carbon stocks: making REDD a reality. *Environ. Res. Lett.,* 2**,** 13.

GOK (2012a) National Climate Change Action Plan Government Printer, Nairobi Kenya.

GUTMAN, P. (2003) From Goodwill to Payments for EnvironmentalServices: A Survey of Financing Options for Sustainable Natural Resource management in Developing Countries. World Wide Fund for Nature (WWF).

HARRIS, N., PETROVA, S., STOLLE, F. & BROWN, S. (2008) Identifying optimal areas for REDD intervention: East Kalimantan, Indonesia as a case study. *Environmental Research Letters* 3 3.

HAWKINS E, THOMAS E. FRICKER T, CHALLINOR A., FERRO, C., HO C., AND OSBORNE T. (2013) Increasing influence of heat stress on French maize yields from the 1960s to the 2030sGlobal Change Biology Issue 19, (3) 937–947

IPCC (2001) Summary for policymakers. Climate change 2001: Impacts, adaptation, and vulnerability: A report of working group II of the IPCC. Geneva, IPCC.

IPCC (2007) *Impacts, Adaptation andVulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press, Cambridge, UK

JINDAL, R., SWALLOW, B. & KERR, J. (2008) Forestry-based carbon sequestration projects in Africa: Potential benefits and challenges *Natural Resources Forum* 32 116–130.

KENYA METEOROLOGICAL DEPARTMENT (2012) Precipitation readings from meterological sub-station of Kenya. IN KENYA METEOROLOGICAL DEPARTMENT (Ed.). Nairobi, Government Printer.

KENYA NATIONAL BEUREAU OF STATISTICS (2007) Kenya Integrated Household Budget Survey 2005/2006. IN KNBS (Ed.). Government Printer, Nairobi, Kenya.

KENYA NATIONAL BEUREAU OF STATISTICS (2011) Statictical abstract. Government Printer Nairobi Kenya

KOLLMUSS, A., ZINK, H. & POLYCARP, C. (2008) Making Sense of the Voluntary Carbon Market. A Comparison of Carbon Offset Standards. Stockholm Environmental Institute.

LECHMERE-OERTEL, R. G., COWLING, R. M. & KERLEY, G. I. H. (2005) Landscape dysfunction and reduced spatial heterogeneity in soil resources and fertility in semi-arid succulent thicket, South Africa. *Austral Ecology,* 30**,** 615-624.

LEICHENKO, R. & O’BRIEN, K. (2002) The dynamics of rural vulnerability to global change: the case of Southern Africa *Mitigation and Adaptation Strategies for Global Change,* 7.

LIN, L., SILLS, E. & CHESHIRE, H. (2014) Targeting areas for Reducing Emissions from Deforestation and forest Degradation (REDD+) projects in Tanzania. *Global Environmental Change*.

LOBELL, D., CAHILL, K. & FIELD, C. (2007) Historical effects of temperature and precipitation on California crop yiels *Climatic Change,* 81 187-203.

LUERS, A. (2005) The surface of vulerability: an analytical framework fro examining environmental change. *Global Environmental Change,* 15**,** 214- 223.

LUERS, A., LOBELL, D., SKLAR, L., ADDAMS, C. & MATSON, A. (2003) A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico *Global Environmental Change,* 13 255 - 267.

MBOW, C., SKOLE, D., DIENG, M., JUSTICE, C., KWESHA, D., MANE, L., EL-GAMRI, M., VORDZOGBE, V. & VIRJI, H. (2012) *Challenges and Prospects for REDD+ in Africa: Desk Review of REDD+ Implementation in Africa,* Copenhagen, Global Land Project Report No 3.

MINISTRY OF AGRICULTURE - CENTRAL PLANNING UNIT (2012c) Economic Review of Agriculture. IN MINISTRY OF AGRICULTURE (Ed.). Nairobi, Government Printer.

NKAKO. M, LAMBRECHTS. C, GACHANJA. M & WOODLEY, B. (2005) Maasai Mau forest status report of 2005 Ewaso Ngiro South Development Authority, Narok, Kenya

NKEM, J., SOMORIN, O., JUM, C., IDINOBA, M., BELE, Y. & SONWA, D. (2012) Profiling climate change vulnerability of forest indigenous communities in the Congo Basin. *Mitigation and Adaptation Strategies for Global Change***,** 1-21.

PEREZ, C., RONCOLI, C., NEELY, C. & STEINER, J. (2007) Can carbon sequestration markets benefit low-income producers in semi-arid Africa? Potentials and challenges. *Agricultural Systems,* 94**,** 2–12.

PETERS-STANLEY, M., GONZALEZ, G. & YIN, D. (2013) Covering New Ground State of the Forest Carbon Markets 2013. Washington, DC, Ecosystem Marketplace.

PLACE, F., ANDATO, M., HEBINCK, P. & OMOSA, M. (2006) Impacts of agro-based soil fertility replenishment practices on the poor in western Kenya. Washington, IFPRI Research Report no 142

RAVALLION, M., CHEN, S. & SANGRAULA, P. (2009) *Dollar a day*, The World Bank Economic Review, 23 pp163-184

REPUBLIC OF KENYA (2009) The 2009 National Population and Household Population Census. Government Printer, Nairobi Kenya. .

REPUBLIC OF KENYA (2010a) Kenya National Climate Change Response Strategy. Government Printer Nairobi, Kenya

REPUBLIC OF KENYA (2010b) The Constitution of Kenya Government Printer, Nairobi, Kenya

REPUBLIC OF KENYA (2012a) National Climate Change Action Plan Government Printer, Nairobi Kenya.

ROBINSON, L. & BERKES, F. (2011) Multi-level participation for building adaptive capacity: Formal agency-community interactions in northern Kenya. *Global Environmental Change***,** 1185-1194

SCOONES, I. (1998) Sustainable Rural Livelihoods: A Framework for Analysis *IDS Working Paper No. 72. Brighton: Institute of Development Studies at the University of Sussex.*

SILLS, E., MADEIRA, E., SUNDERLIN, W. & WERTZ-KANOUNNIKOFF, S. (2009) The evolving landscape of REDD+ projects. IN ANGELSEN, A. (Ed.) *Realising REDD+National strategy and policy options.* Bogor, Center for International Forestry Research.

SIMELTON, E., FRASER, E. D. G., TERMANSEN, M., FORSTER, P. M. & DOUGILL, A. J. (2009) Typologies of crop-drought vulnerability: an empirical analysis of the socio-economic factors that influence the sensitivity and resilience to drought of three major food crops in China (1961–2001). *Environmental Science & Policy,* 12**,** 438-452.

SINCLAIR, T. R. & SELIGMAN, N. (2000) Criteria for publishing papers on crop modeling. *Field Crops Research,* 68**,** 165-172.

STERN, N. (2006) The Economics of climate change: The Stern review. . Cambridge, UK: Cambridge.

TOL, R. S. J. (2005) Emission abatement versus development as strategies to reduce vulnerability to climate change: an application of FUND. *Environment and Development Economics,* 10**,** 615-629.

UN-REDD (2008) Framework document collaborative program on reducing emissions from deforestation and forest degradation in developing countries (UN-REDD), Technical

series, UN-REDD program; available at http://www.un-redd.org/ (retrieved on 13.10.10).

UNFCCC (2009) The Copenhagen Accord: Report of the Conference of the Parties on its Fifteenth session held in Copenhagen, 7.18 December 2009. FCCC/CP/2009/L.7.

VINCENT, K. 2007. Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change,* 17**,** 12-24.

WORLD BANK (2011) BioCarbon Fund Experience; Insights from Afforestation and Reforestation Clean Development Mechanism Projects The World Bank, Washington DC.

WORLD DEVELOPMENT REPORT (2008) World Development Report 2008: Agriculture for Development. Washington, DC., The World Bank.

ZOMER, R., TRABUCCO, A., VAN STRAATEN, O. & BOSSIO, D. (2006) Carbon, land and water: A global analysis of the hydrologic dimensions of climate change mitigation through Afforestation/reforestation. IWMI Research Report 101, Colombo, Sri Lanka: IMWI.