**A Framework and Analysis of Coupled Natural and Human Systems, Kakamega Forest, Kenya**

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**Abstract**

In our study of the Kakamega Forest in western Kenya, we develop an interdisciplinary, coupled natural and human (CNH) framework to analyze the outcomes in this complex social-ecological system. As a biological hotspot and Kenya’s only remaining tropical rainforest, over 2.1 million people, a majority of whom are educationally and economically disadvantaged, surround the Kakamega Forest. As a result, most people living near the forest are highly reliant on all forms of subsistence harvest of forest products for food, income and fuel and deforestation has consumed 90% of the early 20th century footprint. To combat this tragedy of the commons, the Kenyan government passed the Kenya Forest Act in 2005 establishing the Kenya Forest Service (KFS), splitting regulatory authority between the KFS and Kenya Wildlife Service (KWS), and directing the KFS to engage in decentralized Participatory Forest Management (PFM) practices with Community Forest Associations (CFAs). Using a combination of ecological indicators and governance variables collected through biological fieldwork, stakeholder interviews, and document analysis, we apply this CNH framework to provide an initial assessment of the governance and conservation outcomes and untangle some of the complex couplings of this CNH system.

**Introduction**

Globally, human-driven deforestation and the resulting loss of biodiversity are increasingly problematic. Ecosystem services including water purification, erosion control, carbon sequestration, and climate regulation are undermined by overuse of valuable natural resources, especially forests. In order to avert this tragedy of the commons, people are employing different strategies to find an acceptable balance between human need and conservation. While strict no-use policies better support conservation and preservation ideals, they are exclusive and undemocratic. Many people depend on the natural resources for their subsistence, have extended histories using the resources, and demand a voice in decision-making. Thus, strict conservation ideals conflict with more utilitarian designs for common pool resource management. One goal of this research is to measure how these conflicting management paradigms compare through social (i.e. governance) and ecological lenses. Understanding how natural resources impact governance and how governance in turn impacts the availability of resources is a common theme in coupled natural human systems work (CNH)(Liu et al. 2007a). Because the Kakamega Forest ecosystem is managed using conservation and utilitarian governance paradigms, this serves as an excellent case for studying a coupled system.

**Kakamega Forest Setting**

The Kakamega Forest is the easternmost remnant of Guineo-Congolian rainforest and the only one of this type in Kenya (Mutoko et al. 2015). The forest harbors 20% of Kenya’s butterflies (>400 species), >400 species of birds, 7 species of primates, 36 known species of snakes, of which many are of West African origin (Wagner et al. 2008), and over 400 species of plants including 150 tree species (KIFCON 1994). Thus, the forest is considered a biodiversity hotspot and has the third highest priority ranking for conservation among Kenyan forests by the International Union for Conservation of Nature (IUCN; Wass 1995).

The Kakamega Forest spans 23,000 ha (hectares) of Kakamega and Vihiga Counties in Kenya’s western region (Figure. 1). The forest lies between 0°10′ and 0°21′ North and longitudes 34°47′ and 34°58′ East, and has a varied topography with altitude ranging between 1,250 m – 2,000 m above sea level (Tsingalia 1988). Annually, the Kakamega Forest receives 1,500-2,000 mm of rainfall, with two rainy seasons occurring from March-June and July-October (Esther 2014). The forest is comprised of closed indigenous forest, indigenous plantations, non-indigenous plantations, and grasslands. Currently, six distinct forest fragments make up the Kakamega ecosystem, with the main Kakamega forest block covering 8,537 ha. The other forest fragments include Ikuywa (1,370 ha), Bunyala (1,199 ha), Kisere (420 ha), Malava (190 ha), and Kaimosi (132 ha). These smaller forest fragments have been separated from the main forest block for at least 35 years (Mitchell 2004). Approximately 1,592 ha of the forest is non-indigenous plantation (Guthiga & Mburu 2006).

The Kakamega forest is situated within one of the most densely populated rural areas in the world (Kakamega County 1.6 million: 542 people/km2; Vihiga County 0.5 million: 1,045 people/km2), with over half of the people surviving on <$1USD/day (KNBS, 2015). The main economic activities include subsistence farming, small-scale businesses, and temporary or permanent employment. The majority of people living adjacent to the forest belong to the Luhya tribe, the second largest ethnic group in Kenya comprised of 18 clans, each having a distinct dialect. Most of these people rely on harvesting forest products for subsistence use; as >90% households around the forest use wood from the forest for fuel (Bleher et al. 2004). Other forest uses include charcoal, timber, medicine, meat, fruits, honey, beekeeping, grazing, and grass for thatching houses and as livestock fodder (Ouma et al. 2010).

Areas adjacent to the forest have high agricultural potential due to good climate and soil conditions, but because of high population, the agricultural land is divided in to small parcels which people grow food crops on (e.g. maize and beans) for household consumption and for sale at local markets. However, these small plots are often insufficient to supply subsistence needs and people turn to the forest. Thus, a central challenge in managing rainforests in high population regions is reconciling the local subsistence needs with conservation interests to ensure the continued availability of those resources.

**Kakamega Forest Policy History**

Kakamega Forest’s northern boundary was established in 1913-14 and managed by the Local Native Council (Mitchell 2004). Because the southern area of the forest remained open for settlement and coffee growing, the Kakamega became separated from the South Nandi Forest (Mitchell, Schaab, and Wagele 2009). The colonial government became actively involved in forest issues beginning in the 1930s, responding in part to a gold rush in the district and the resulting demand on forest resources (Mitchell 2004). In 1933, the Kakamega, Kisere, and Malava Forests were first gazetted with Bunyala following much later in 1956 (Mitchell 2004). Between the 1930s and 1980s, indigenous tree harvesting was pervasive in the region with the Kenya Forest Department replanting some species of indigenous trees throughout the 1940s-50s and switching to faster growing exotics during the 1980s-90s (Mitchell 2004; FD & KWS 2005). As part of this forest regeneration policy, the “shamba system” was first implemented in the 1940s where people were allowed to grow agricultural crops while tending tree seedlings within the forest (Oduol 1986). Pervasive abuses of this system including tree seedling sabotage and squatter’s right claims spurred the government to evict the shamba farmers from the forest and terminate the program in 1986 (Emerton 1992). Indigenous tree harvesting was also banned during this time and the Kenya Wildlife Service (KWS) was brought in to manage the newly established Kakamega and Kisere National Reserves within the forest.

Since the Kakamega was first gazetted, it has been managed by several different government agencies (Althof 2005). In 1991, the Forest Department and the KWS entered into a memorandum of understanding to oversee management of forests in Kenya whose biodiversity was threatened (Guthiga & Mburu 2006). This agreement was replaced by the 2005 Kenya Forest Act, which dissolved the Forest Department and replaced it with the Kenya Forest Service (KFS). As mandated by the 2005 Kenya Forest Act, the KFS uses a decentralized Participatory Forest Management (PFM) approach, where Community Forest Associations (CFAs) work with the KFS to develop management and conservation policies associated with consumptive use of the forest within their gazetted regions (Wabusya and Tsingalia 2012). Thus, PFM involves the central government forming partnerships with organized local community groups to co-manage the forest with sustainability, biodiversity conservation, and socio-economic objectives in mind (Ongugo, Mogoi, Obonyo, and Oeba 2008; Wabusya and Tsingalia 2012). Presently, the forest ecosystem is managed by two semi-autonomous government agencies, the KWS that governs approximately 20% of the northern section of the Kakamega Forest and the KFS that governs the remaining 80% (Kefa and Gregory, in press).

As outlined in the 2005 Forest Act, PFM is a decentralized governance approach that enables people in the forest adjacent communities a voice and role in the decision-making process of forest management, including policy formulation and implementation. Throughout the developing world, PFMs are increasingly employed to manage forest resources giving local communities power, participation, and legal authority in land-use decision-making processes. The CFAs comprised of local community members must develop a constitution, define their purpose, identify election procedures, justify budgeting, and obtain legal standing through Kenya’s Register of Societies (2005 Forest Act; Wabusya and Tsingalia 2012; personal interview 2016). Importantly, CFA members can legally harvest forest products with the purchase of a permit at Ksh100 (~1USD) per month (KFS report, 2012). Initially, several CFAs including the Kibiri CFA, Bunyala CFA, and Muileshi CFA arose in the Kakamega ecosystem to join the KFS in and County governments in the co-management of forest resources (Ongugo et al. 2007), with the Muileshi CFA emerging as a leader. Importantly, the Muileshi CFA co-authored and signed a 10-year Forest Management Plan with KFS in 2011 to co-manage the forest (Wabusya and Tsingalia 2012).

Conversely the KWS applies a strict, no-use management approach, which prohibits any form of consumptive utilization of the forest products (Mburu & Birner 2007). Eco-tourism and research activities are allowed but closely regulated. These protected areas are governed by fence and fine, coercive conservation, or fortress conservation strategies and have been criticized because they exclude local populations, prevent extractive uses, minimize human use, and are undemocratic (Adams and Hutton 2007). Violating these policies will result in arrest, jail time and fines. While the ecosystem and Kenyan national government benefit from this arrangement, local communities are left behind. Despite these extreme conservation policies, past surveys have identified that local communities were more satisfied with KWS management strategies and valued conservation more than other management regimes (Guthiga and Mburu 2006). However, the more restrictive KWS policies have been criticized because they do not benefit the local people and by default incentivize people to break the law to obtain needed forest products illegally (Kiplagat et al. 2008). However, the inclusive approach used by KFS has also been criticized, because it is perceived to encourage overexploitation of the forest resources, resulting in a tragedy of the commons scenario (Röhss 2012).

**Coupled Natural and Human (CNH) Systems Framework**

CNH scholars have struggled conceptually and theoretically to mesh the natural and social science perspectives due to ontological and epistemological differences. These differences coupled with the inherent complexity of CNH research has resulted in numerous but disjointed theoretical and empirical research tracks. For example, An (2012) catalogs a number of agent-based models used by CNH scholars to explain/predict human decision-making and the models run the gamut from microeconomic and psychosocial/cognitive to institution-based and heuristic. Previous CNH researchers have analyzed sustainable rangeland ecosystem management in the Hindu Kush-Himalaya (HKH) region using more descriptive case studies with the conceptual focus on monitoring and enforcement, economic and ecological benefits, and environment policy implementation (Dong et al. 2009). Although informative, these case studies lacked clearly articulated policy and economic theory underpinnings.

In coupled natural human systems, people and nature reciprocally interact to form complex feedback loops (Liu et al. 2007a, b). Traditional ecological based approaches to forest management, which view dynamic human interactions as a unidirectional detriment to biodiversity, fall short of achieving forest conservation, largely because such approaches fail to recognize that conservation is a dynamic coupled natural and human system process (Liu et al. 2007a). For example, in Wolong Province China, people rely on subsistence wood harvest, and that harvest threatens giant panda (*Ailuropoda melanoleuca*) conservation necessitating regulations to limit access to reserve areas. However, this has had the unintended consequence of actually increasing deforestation because reserve areas have concentrations of highly desirable woods resulting in increased illegal harvest (An et al. 2005).

Governance plays a crucial role in how people interact with and use the forest, and we draw from an interdisciplinary canon of environmental governance literature (Ostrom 1990, 2007; Persha, Agrwal and Chhatre 2011). Governance is defined as “the formal institutions and regimes empowered to enforce compliance, as well as the informal arrangements that people or institutions have agreed or perceive to be in their interest” (UN Commission on Global Governance, 1995: 2e 4).Ostrom (2009) offers a framework for analyzing outcomes in social-ecological systems (SES) that includes governance and we modify and apply this conceptual CNH for this study (Figure 2). The framework identifies four first-level core subsystems of a SES (resource system, resource units, governance and users) as well as the larger social, economic and political settings and related ecosystems.



**Data Collection and Methods**

We employ a mix of qualitative and quantitative research methods. For the social science qualitative research section, we conducted nine individual interviews and one group interview of Kakamega Forest stakeholders during the summer of 2016. The interviewees represent a variety of different perspectives including: KWS and KFS forest managers, the Ecosystem Conservator, Muileshi CFA leaders, a private forest landowner, an ecotourism guide, a community based organization (CBO) women’s pottery group leader, and several representatives from ECO2Librium, a local organization working for socioeconomic empowerment and sustainable conservation solutions. Participants in the group interview also represented a wide variety of stakeholders representing CBOs including grass cutters, ecotourism guides, Muileshi CFA leaders, Muliro Farmer’s Conservation Group, ECO2Librium representatives, and KEEP (Kakamega Environmental Education Program) officials. We followed standard international and Bowling Green State University human subjects protocols for interviews, recorded and transcribed the interviews, and coded them using both analytically-based and research derived categories (Ostrom 2009; Yin 2003; Corbin and Strauss 2008). See Attachment 1 for the interview Codebook.

The biological and ecological data were collected as part of a Masters thesis and for purposes of brevity, we refer to the following documents for a complete description of these methods (Kefa 2015; Kefa, Lung, Espira, and Gregory 2016; Kefa et al. under review). Cumulatively, these studies measure forest biodiversity and how human use (wood harvesting, tea plantations, energy efficient stove projects, etc.) impacts biodiversity. While this paper focuses primarily on the qualitative interview data, we use the results from the biological investigations to draw conclusions regarding the CNH interactions.

**Results**

**Qualitative Analysis**

Several key themes emerge from the analysis of Kakamega stakeholder interviews. From the KFS perspective, the PFM established by the 2005 Kenya Forest Act and the co-management ideals represent an improved governance strategy. The Ecosystem Conservator calls the PFM a success story because “they don’t have to use a lot of energy and resources to protect the forest. CFA’s play a positive role and improved the way we manage the forest.” The PFM also “sensitizes the people to regulations (helping people) know what is legal. PFM is co-management and community monitoring.” One forest manager adds that co-management also means the community must benefit more than the government, but the community has specific responsibilities and clear rules established by the 2005 Forest Act. Using the forest means community members must join CFAs, pay to use the resources (i.e. firewood collection), and volunteer to promote conservation. The community owns the forest but these property rights must be earned and paid for, according to one forest manager.

One form of co-management that receives mixed feedback from several KFS and Muileshi CFA leaders is that of monitoring and enforcement by KFS rangers and CFA volunteer scouts. Several group interview participants also view their role as additional monitors on forest use as a benefit. However, the lack of resources, scouts work for free and forest rangers are not paid well, creates implementation problems. Reports of illegal activities from scouts and other CFA members are not followed up on immediately, undermining enforcement and sanctioning for rule-breaking. Illegal harvesting and use of the forest remains an issue, despite efforts from the community and KFS to enforce the 2005 Act.

Another sensitive issue and common theme centers around corruption. Numerous stakeholders bring up the issue of corruption in general terms but were careful not to mention specifics. Fears of reprisals and KFS officials revoking forest use permits tempered this dialogue. Claims of corrupt rangers being paid to ignore illegal harvesting and charcoal burning, forest managers accepting bribes, and CFA leaders hoarding forest benefits emerged during the interviews. Despite these corruption claims within all levels of forest co-management, many interviewees implied that corruption was limited to specific individuals. Determining whether corruption is systemic within the Kakamega Forest ecosystem co-management regime or isolated to individuals is beyond the scope of this study. However, it remains an issue to stakeholders and undermines monitoring, enforcement, and sustainable use ideals of the law.

Stakeholders, almost unanimously, call for greater education and training to enable greater forest conservation. One person asserts that more conservation training, information sharing, and self-organization training is needed, drawing on intellectual resources from local to international universities and non-government organizations. This conservation ethic, however, is difficult to balance against the livelihood and subsistence needs of the surrounding forest community. As the Ecosystem Conservator and several community organizers noted, abject poverty and the high population density of surrounding communities poses a significant challenge to conservation. “One cannot do conservation on an empty stomach.” While the community utilization aspect of the 2005 Forest Act enables the legal permitting and licensing of forest harvesting, people take advantage of it. For example, “A mother comes with 4 children and even with a permit, the whole family comes . . . (they) consider it to be a family license. Men don’t come. They refuse. All girls. Question, to arrest the mother or arrest the children?” From the forest managers to the Ecosystem Conservator, improving the economic well-being, supporting local livelihoods, and collaborating with the community are priorities but the KFS “does not have the power to invest in them.” This lack of resources is pervasive, as exemplified by one forest manager who did not have a computer, firearm for protection, or even a locked file cabinet to store records. The same forest manager views the synergies derived from community outreach and training as vital to forest conservation.

* “So people are coming here in big numbers so that I train them how to go prune trees then they carry home. That is the firewood now. They have helped me manage the forest through pruning and they carry the wood home. I have solved the problem. They will manage the forest. And they will own it; you know it just depends on the manager on the ground. It is you to make sure to try your level best to make these people understand that this forest is theirs. They should own it; I’m just a servant. I’ve come here to help you to manage your own forest. Can you make sure the forest is restored to the right…in the right position.”

Not only does firewood collection monitoring and enforcement pose a problem, but the commercial extraction and harvesting of tree plantations emerges as a co-management issue. CFA members assert that plantation harvesting notification and permits are not available to the general public. These resource access, revenue sharing, and communication challenges emerge as one significant co-management problem. Muileshi CFA leaders stress the importance of community empowerment through forest co-management, sustainable income generating activities and external funding sources. “We need some economic empowerment. Because we have to give back to the community of many people; we need money and, in addition to that to open more income generating activities for the community so that they can get concentrated and get their daily bread. There are so many activities that once you give to the community, they won’t go in and destroy the forest.” A forest manager also echoed these concerns over the tragedy of the commons by stating, “I’m really worried as the forest station manager, and that is why I am working hard to ensure that these people get income generating activities so that they don’t just look at the forest alone. They should also do other things to supplement their needs. Because if we put every mind in the forest, every need in the forest, they will deplete the forest.”

Despite the outreach and education efforts from some KFS forest managers, a communication gap exists between the KFS, CFAs, and the surrounding populations. For example, the 2005 Forest Act calls for a Local Level Management Committee, comprised of CFA leaders and KFS officials to meet 3-4 times per year to serve as a venue for co-management and problem solving. CFA leaders assert that they have met only 3 times since their Participatory Management Plan was developed in 2011. CFA leaders take partial responsibility for this communication failure but assert the KFS has not wanted to meet. CFA members also view the forest use regulations regarding licensing and permitting as unclear, inaccessible, and poorly communicated. Several stakeholders add that property rights are unclear and that the KFS top management reaps the majority of forest benefits instead of the community.

Communication difficulties abound within the CFAs as well. For example, several stakeholders assert that the CFA should be representing members’ requests and communications to the KFS but they are not. Similarly, the relationship between the CFAs and the user groups (CBOs) is unclear. One stakeholder views the CFAs as an umbrella organization that should help coordinate user group activities, negotiate, lobby, and communicate to the government in order to problem solve and enable socioeconomic development. CFA members and CBOs echo these sentiments and would like to see a more clearly defined role for the CFAs. These roles are somewhat muddied by the complexity of the regulatory design. For example, each forest section must first have an approved Forest Management Plan and then the CFAs work with the KFS to develop a Participatory Management Plan – a process than can take up to three years. Thus, to understand how the regulatory regime works, one must not only know the contents of the 2005 Kenya Forest Act but also the details of the Forest Management and Participatory Management Plans.

**Quantitative Analysis**

Our recent research into the efficacy of these different governance structures (KFS vs. KWS) and their social and ecological outcomes yields several unique results. Kefa and Gregory (*in Press*) have found these forest management practices are resulting in pockets of rare indigenous tree species and that wood from these trees sells for up to 25% more than nonindigenous wood. In response to these premium prices, people are selectively harvesting rare native woods that are predominantly found in KWS managed areas; where the penalty for wood harvest carries a mandatory prison sentence. To circumvent this, people access KWS through KFS managed areas and send children into KWS areas of the forest to harvest rare native species (Kefa and Gregory *in Press Oryx*).

We also evaluated the degree to which KWS and KFS management impacts human use and biodiversity of the forest. In addition, we also evaluate the regional conservation initiatives: tea plantations and wood-efficient cook stoves are impacting human use of the forest. We found that KWS managed regions had higher tree species diversity and more rare trees than did KFS managed areas. We also observed that rare indigenous tree species are preferentially harvested by humans and there exists a bidirectional influence of human use on forest biodiversity, and forest biodiversity on human use. These data suggest that conservation of Kakamega forest is linked to social and economic development of the people living near it and therefore, its conservation needs to be approached through integration of effective forest resource management and economic empowerment of people living near it.

**Conclusions**

**Attachment 1**

**Kakamega Codebook**

1. Governance
	1. Government Organizations
		1. Kenya Forest Service (KFS)
		2. Kenya Wildlife Service (KWS)
		3. County
	2. Non-governmental Organizations
		1. Community Forest Associations (CFA)
		2. KEEP
		3. Eco2Librium
		4. Other
	3. Participation
		1. Voice
		2. Transparency/Accountability/Right to Know
		3. Deliberation
		4. Conflict
		5. Lobbying
		6. Networking (local to international)
		7. Information sharing
	4. Self-Organization
		1. Training/education
	5. Communication
		1. Clear/Unclear
	6. Governance Roles
		1. Hierarchy
		2. Clear/Unclear
		3. Economy (revenues; employment)
	7. Corruption
	8. Regulations and Rules
		1. Clear/Unclear
		2. Monitoring
		3. Enforcement
		4. Sanctioning/penalties
		5. Management and Management Plans
		6. Quality
	9. Resources
		1. Personnel
		2. Funds
	10. Property-rights
		1. Clear/unclear
		2. Defined
2. Users
	1. Type of use (farming, tree harvesting, butterfly, beekeeping, tourism, plantation, seedlings)
	2. Socioeconomic attributes
	3. History of use (entitlement)
	4. Location
	5. Leadership/entrepreneurship
	6. Norms and social capital
	7. Knowledge of SEES/resource
	8. Values
	9. Extraction
	10. Conservation
	11. Sustainability
	12. Funding
	13. Education
		1. Who? Type of user
		2. Location - local
		3. Training
		4. Research
	14. Naming
	15. Metaphors
3. Corridor Species/Units
	1. Economic value (costs/benefits)
	2. Species named
	3. Corridor size