Linking farmer, forest and watershed: Understanding forestry and soil resource management along the upper Njoro River, Kenya

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ABSTRACT

This paper describes subsistence farmers' soil and forestry management techniques and their implication for watershed managers and policy makers in the Upper Catchment of the River Njoro (UCRN) in Kenya. This research seeks to answer the following questions: How do farmers in the UCRN view and manage soil and forestry resources? What does this imply for development and conservation planners concerned with watershed and environmental services? The study blends social science approaches and biophysical assessment. Interviews were conducted between July and September of 2003 with a sample of 15 hillside farmers located within 200 meters (m) of first order streams or springs. Questions addressed agronomic practices, economic issues, the use of local tree resources, soil management perceptions and practices, and farmer awareness of landscape ecology and hydrology. Biophysical data included inventory, frequency and use of on-farm tree species, soil samples, and GPS points for each farm. Laboratory tests revealed soil quality indicators. This paper presents UCRN farmer perceptions of soil fertility and yields from the interviews and compares these perceptions to an agronomic analysis of yield limitations. Use and perception of forestry resources by farmers is also described in relation to large-scale agroecological processes, such as altered hydrologic cycling and soil erosion under new land use and cropping patterns. This information is compared with biophysical data to identify "gaps" between local and scientific knowledge. Consideration of biophysical characteristics of these upland agroecosystems in tandem with farmer perception and management provides insight for environmental planners concerned with the promotion of improved farm and land use systems (LUS) in the highlands of East Africa.

1. INTRODUCTION

Across the globe, increasing attention is being paid to the importance of watershed management for the continued provision of environmental services. In Kenya, the significance of these issues became prominent after the publication of news regarding the drying of perennial streams on the slopes of Mount Kenya (The Nation 2002) and the eutrophication of Lake Victoria, Africa's largest single body of fresh water (Walsh

2002; Swallow et al. 2001). Consequently, increased attention has been given to the importance of upland areas in the maintainance of watershed functioning. Because upland regions tend to be inhabited by poorer segments of the population (Cook et al. 2002), ecological analysists are frequently concerned by relationships between poverty and environmental degradation. For many years, it was generally accepted that the relationship between the two could be described as a downward spiral whereby poverty forced the degradation of the environment that in turn would heighten poverty (World Commission on Environment and Development 1989). While this "environmental orthodoxy" has by and large been discounted (Cook et al. 2002; Leach and Mearns 1996), there nonetheless remains the distinct possibility that impoverished actors operating in an *already degraded* environment possess the potential to negatively impact the natural resource base, thus compromising environmental services.

In order to develop appropriate watershed management plans that alleviate poverty whilst maintaining these services, research must be conducted in a participatory matter that accounts for the needs, perceptions and desires of the local population (Kerr et al. 2002; Hinchcliffe et al. 1999). This study provides an analysis of how UCRN farmers perceive and utilize soil and forest resources in relation to large-scale ecological processes, namely hydrological cycling and the maintenance of agroecological services. Because the vast majority of UCRN farmers' livelihoods are *directly* sustained by the natural resource base, they are at once the primary stakeholders and managers of upland resources (Cook et al. 2002).

This study was developed as part of a larger research endeavor, the Sustainable Management of Watersheds Collaborative Research Support Project (SUMAWA-CRSP), based at Egerton University in Kenya. SUMAWA-CRSP is an international collaboration involving the University of Wyoming, the University of California at Davis, Utah State University, Egerton and Moi Universities in Kenya, and Kenyan Government partners. It aims to demonstrate and develop integration of scientific and local knowledge to support sustainable stakeholder-based management of watershed resources through local dialogue, planning, and action.

The continuance of watershed services depends upon a complex set of interactions between biophysical and human-related forces. Using methods that integrate the natural and social sciences with local participation, SUMAWA-CRSP was established in response to growing concern that recent human settlements in the UCRN, coupled with poor land use practices (including improper agricultural and grazing systems in concert with increasing population pressures) have resulted in the rapid deterioration in the watershed's condition. Settlement within the whole of the catchment area has been under way for several decades (Daniels and Bassett 2002), although the population in the upper reaches of the watershed has expanded particularly in the last decade following the clear felling of degazetted forested lands. SUMAWA-CRSP's overarching goal is to support local communities in the effective identification and execution of locally tailored solutions that enhance both hydrological functioning and environmental services.

1.1 Research focus

This research is focused on farmers cultivating in close proximity (within 200 m) of riparian zones in the UCRN. Given the established importance of such areas for critical watershed services (Cohen 1997), it is necessary to develop a thorough understanding of predominant land use systems in the UCRN and their relation to landscape scale ecological processes. The majority of the UCRN's inhabitants would easily be classified as falling below the poverty line as measured by various international organizations (UNDP 2002; World-Bank 2002). They could also be classified as "investment poor" (defined as unable to make investments to improve the natural resource base to sustain agroecological services) due to a number of factors, not exclusive to financial restrictions that impede farmers from investing in resource conservation techniques (Reardon and Vosti 1995). When compared to Kenya and Sub-Saharan Africa agricultural yields in the UCRN are generally low and market returns to labor for agricultural products are poor. Because 'legitimate' non-farm employment is rare, it is thus logical that upland residents augment their income through the extraction of profitable products from the UCRN's already depleted natural resource base. Specifically, the collection and sale of fuel wood/charcoal are cited by farmers as lucrative, especially when compared to agricultural production alone. Because upland forests provide benefits in terms of watershed and environmental services, the dynamics between agricultural land use systems and on-going forest exploitation in the UCRN is an important concern for watershed planners.

Understanding the dynamic relationship between farmers, forests and watersheds entails a thorough accounting of farmers' current perceptions and management actions relative to the natural resource base. The research areas addressed in this paper include the following sub-questions:

- What agricultural and forest use practices are employed by UCRN farmers?
- How do farmers understand larger environmental processes such as hydrological cycling in relation to farm and forest use?
- Are there significant differences in soil quality associated with various agricultural practices?
- Are there other agronomically limiting factors in UCRN cropping systems?

1.2 Study location and environment

The Njoro Watershed is located near the eastern crest of the Mau Hills Escarpment that borders East Africa's Rift Valley (Krhoda 1988) (Fig. 1). This study is broadly relevant to water resource issues in Kenya and is underscored by the recognition that the River Njoro Catchment as part of the Mau Hills more generally, represents one of five major 'water towers' in Kenya (FMF 2001).

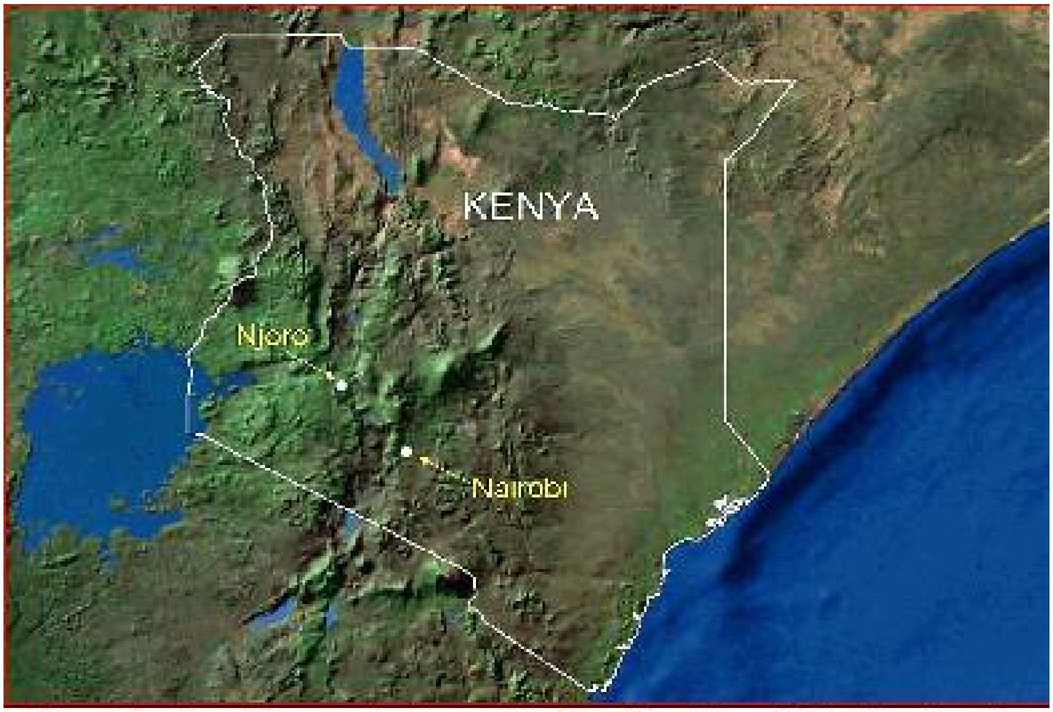

Figure 1. Location of the research study area. The River Njoro is located in the rift valley and flows into Lake Nakuru National Park. Like other rift valley lakes, there is no outlet path to the sea. Lake Nakuru is thus rather shallow (≈1 m). High rates of evaporation result in an unique Lake ecosystem characterized by saline and alkali water conditions. ***Landsat photograph supplied by S. Miller of the University of Wyoming.***

Comprised of tertiary age lavas, the soils in the upper watershed are classified as Mollic Andisols and are generally fertile (Ministry of Agriculture National Agricultural Laboratories 1980). Originating at an altitude of about 3,000 m above sea level, the River Njoro is a second order stream that has the Little Shuru as it's primary first order tributary. The following information is taken from Jenkins et al. (in press), based on work by Chemelil (1995) and others. The River Njoro is about 60 km long, originating near the peak of Eastern Mau Escarpment at an elevation of 2700-3000 m. The river terminates at Lake Nakuru on the floor of the Rift Valley (≈1722 m). Long-term mean annual rainfall varies from 1200 mm in the UCRN to 800 mm at Lake Nakuru. Precipitation is distributed tri-modally with peaks in April (largest volume), August (second) and November (smallest). The dry season spans from January to March. The long term mean monthly air temperature varies between a high of 18.5°C in March and a low of 13.5°C in August. This temperature regime is generally sub-optimal for an agricultural production system with dependency on maize as the staple crop. Potential maximum evapotranspiration (ET) is estimated at 1150 mm/year, peaking in March. Because annual ET exceeds rainfall in the valley floor, the UCRN provides rainfall capture and supply to the arid valley below. The watershed blankets 302 km^2 of the Lake Nakuru Basin and supplies 39% of the Lake's water inflow from runoff. Tree canopy cover in the hydro-stream area ranges from 0 to 90% (Mathooko 2001). The river has historically become influent as it reaches its terminus at the Lake Nakuru National Park. It is theorized that portions of the river's flow is lost to the porous fissured zones of the Rift Valley floor. More recently, higher portions of the river have run dry and boreholes have failed. This has resulted in public alarm and periodic water rationing by catchment residents.

There are several major land use systems in the upper third of the watershed. These include indigenous and plantation forests, free-range herding, and smallholder agriculture. The farms sampled in this study are located in approximately the mid-upper portion of the watershed in an area about • 8 km^2, stretching between latitudes 0° 23′ S and, 0° 27′ S, and longitudes 35° 40′ and, 35° 53′ E, on both the Little Shuru tributary and the River Njoro (Fig. 2). Elevation ranged from 2400 -2700 m. Above the study area, the landscape is dominated by a patchy matrix of native and plantation forest tracts interrupted by clear felled areas and open pasture. Below this, the watershed stretches through more smallholder farms before being interrupted by large-scale agricultural tracts owned by Egerton University and the town of Njoro. The River Njoro eventually empties into Lake Nakuru National Park, a U.N. declared Ramsar Site famous for its large populations of birds (>495 species), notably the lesser flamingo *Phoeniconaias minor.*

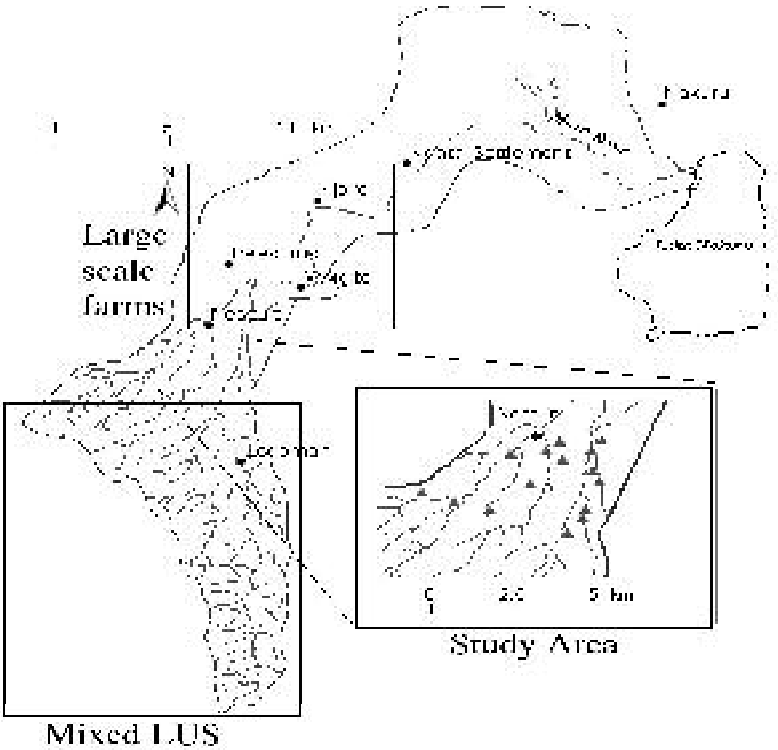

Figure 2 The River Njoro Watershed Boundary. The study area is magnified to the right. Above the study area, the landscape is a patchy network of forest, plantations and pasturelands. Below the study area there are a number of large-scale farms. *GPS map developed by Laura Thel of the U. of Wyoming.*

2. **RESEARCH RATIONALE**

Because the overarching majority of the settlements in the study area are less than ten years old and farm management strategies are were largely unknown, it was deemed critical for SUMAWA-CRSP to develop a thorough understanding of the UCRN LUS. First and foremost, this study responds to this need. However, this research also seeks to investigate broader issues of cropping system strategies, soil quality, farmer perception of soil fertility and forest resources and the potential impact of these LUS on the broad scale watershed environment.

According to Blakie and Brookfield (1987a), land management actions by upstream populations can have important consequences for downstream populations. SUMAWA –CRSP researchers hypothesize that the rapid, recent, and abrupt conversion of tree cover to agriculture may be altering hydrological functioning at the landscape scale, and producing detrimental environmental and hydrologic effects downstream in the UCRN. In tropical forests located on slopes, reduction in biomass in the form of forest litter may result in a decrease in rainfall infiltration and subsequent groundwater recharge (Macdonald et al. 2004). Consequently, high volume surface run-off events can increase during the rainy season and dry season flows can be significantly limited. These presumptions are complicated by the fact that conversion to agriculture can also induce positive long-term effects for net rainfall capture and retention largely because the ET losses from forests are higher than those from agriculture. Nonetheless, the impact of heightened runoff and soil erosion potential during the forest to agriculture conversion period is a major concern to watershed planners.

2.1 The importance of Upland LUS

Riparian zone vegetation (specifically tree cover) is positively associated with watershed services, namely the control of erosion, the restriction of pollutant flows into the river system and regulation of stream flow. Thus, the relationship of upland farming populations to stream edges is of particular interest.

Peter (1984) explained that special emphasis should be placed on the conservation of upland Riparian zones (RZ) because of the numerous environmental services and habitats offered by these edge-ecosystems. Moreover, agricultural activities near riparian zones are also potentially harmful to river health. Understanding bordering farmers' perception of RZ vegetation is thus helpful in the later design of cropping strategies and policy interventions that could assist in the restoration of damaged RZ's.

Consequently, two sub-goals of the SUMAWA-CRSP project include (a) the conservation of existing forest and riparian vegetation stands and (b) the promotion of reforestation efforts. Because much of the UCRN has come under increasing habitation, these efforts will have to take some form of community forestry or agroforestry. Although the environmental services provided by such efforts are as comprehensive as those supplied by natural forests (hydrological regulation, etc.), these projects could help to relieve existing pressures on remnant forest tracts by supplying useful products such as fuel wood (Arnold and Dewees, 1999).

2.2 Trees and the maintenance of upland hydrology

Krhoda (1988) predicted the effects of poorly planned land use and clear felling of forest stands in the E. Mau. According to his hydro-geological assessment, "…any type of resource utilization in the Mau Hills forest…will have some impact on the hydrological regime…what ever method of land use is applied, it will be necessary to exercise strict management practices." Because of a dramatic loss of 28% of the E. Mau's forest cover has occurred since 1967 (FMF 2001), his concerns regarding altered landscape dynamics should be taken very seriously. Krhoda (1988) predicted that clear felling of forests and subsequent cultivation of the land with annual crop patterns would result in the "rapid degradation" of land and subsequent "mass wasting[1]."

Highland forest catchments in semi-arid basins are partially credited with the regulation and maintenance of stream flow. Because forest canopies intercept raindrops before they strike the ground, the high intensity-kinetic energy of the drop is reduced. Therefore, raindrop impact on the soil surface is for the most part more gentle than it

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[1] Whether these predictions will turn out to be correct has yet to be determined: there remains the possibility that the hydrology of the UCRN will in time readjust to the advent of new land use systems.

might have been if the rain path were uninterrupted. This assists in the increased infiltration of water into the soil subsystem as the potential for splashing, crusting and compaction of the soil surface by raindrop impact is reduced[2]. Without forest cover, precipitation is less likely to recharge soil subsurface storages of water and is more likely to result in increased runoff during and immediately after storm periods if no land management measures are taken. The consequences of this process include heightened potential for downstream riparian flooding during the rainy season, and a reduction of base stream flow during the dry season.

Peasant farmers have long been recognized as economically rational (Shultz, 1964), and in many cases the productivity of their acres holdings has been meticulously maximized in relation to the potential for financial return in the market place (given available inputs). Nonetheless, when poor yields and market returns to labor are insufficient to support farming families, farmers may by default be forced to seek additional income from off- farm employment and enterprise (Blakie and Brookfield 1987a). In the UCRN, the simplest and most feasible (and perhaps most profitable) way to do this is through additional felling of trees in remnant forest and riparian stands. Such actions are not uncommon in the Third World where peasants do not have the ability to invest in capital that could augment on- farm income (Reardon and Vosti, 1995).

3. Historical and Political Background for UCRN management

In any responsible study of human systems, it is of paramount importance to understand the roles played by historical and political forces in shaping the choices that local actors make. The study of environmental management is no exception—both biophysical restrictions *and* social forces impact farmers' attitudes towards the performance of their cropping systems and the use of local resources. Ignorance of historical and political issues undermines the potential to develop successful conservation interventions. Daniels and Bassett (2002) posit that the prevalence of socio-political tensions during the 1990's in the Lake Nakuru Basin could undermine the efforts of conservation organizations interested in implementing participatory resource management plans. Because tense socio-political tensions remain in the UCRN, these issues must be understood in order to better evaluate potential resource management interventions. What follows is a brief account of the region's history coupled with an explanation of the ways in which past socio-political events might impact farmers' perceptions of agroecological processes and management.

Until British settlement during the colonial period, the Eastern Slopes of the Mau Escarpment consisted predominantly of indigenous forests. Even today, the primary woody species include the natives *Juniperus procera* and *Olea europapea* sub. sp. *africana.* Although the region once supported a large diversity of vertebrate animal species, the

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[2] It has been noted that trees could, under some circumstances actually *increase* the potential for forceful raindrop impact. Termed the "Bucket Phenomenon," this condition has been described in situations when drops collects on leaf edges and combine to develop a single, larger and heavier mass (Stocking, 1996). The impact of drops falling from trees can under some circumstances result in their more forceful impact, leading to soil particle detachment and erosion. Nonetheless, this phenomenon is more an exception to the rule than the norm, especially where trees lack concave leaf structures (McDonald et al. 2003; Stocking 1996), as in the Mau Hills forests where trees are comprised largely of needle and broad-leaved species.

recent and increasing degree of human habitation has resulted in their rapid decline (Wakanene et al. 1997). Prior to the advent of the colonial era, the area was sparsely inhabited. However, pockets of the forest were claimed by semi-nomadic Ogiek peoples, who subsisted by hunting, gathering and collecting honey from the beehives placed high in forest tree branches (Ogot 1978).

By the early 1900's, the area had fallen under tight colonial control. Predominantly interested in the extraction of forest timber resources, and to a lesser degree in the establishment of settlements in the fertile valley and slopes in the lower catchment, the incursion of the British forever changed the East Mau Landscape. From 1902- 1908, clear felling of forests increased throughout the mid and upper portions of Njoro Watershed. In some cases these areas were replanted to neatly configured rows of exotic tree species. The advent of the First World War and the increased demand on European colonies to supply raw materials during the war effort dramatically accelerated these trends. To facilitate the establishment of plantations on areas that offered little hope of unaided regeneration, the British developed pioneering agroforestry methods—the "Tyunga" or "Shamba" systems by which Africans were permitted to temporarily settle and cultivate plantation land in exchange for sapling maintenance (Loogie and Dyson 1962).

Under the Shamba system, indigenous forests were converted to exotic soft wood plantations. Kenyan peasant laborers applied to enter into contract with the colonial forest department for temporary land entitlement. This agreement was contingent upon the peasants' agreement to labor for the forest department for nine months out of the year. In return, applicants were allotted pieces of land upon which they planted tree seedlings. Areas between seedlings were designated for annual crop cultivation. The Shamba system was for the most part considered to be a success—peasants supervised the growth of the saplings, earned meager returns for their labor, and raised annual crops (predominantly *Zea mays).* The contracts were terminated after three or four years, around the same time the saplings had grown large enough to preclude cropping. Years later, selective harvesting of timber products occurred. Interestingly, the British enforced forestry policies against the felling of riparian areas by establishing large 'no-cut' zones extending in each direction from stream edges. Apparently, this was done out of an awareness that riparian vegetation provides useful ecological services including regulation of stream flow and hydrology (Carroll, 1947).

Kenya's guerilla war for independence, (1952-1956), brought an abrupt end to these developments. Full autonomy was granted to the Republic of Kenya in 1963 following the Mau Mau rebellion. Forest development and extraction in the UCRN did not resume for quite some time there after. Until 1984 Nakuru District still retained ≈98,848.6 ha of intact forest, ranking it third in terms of total forest cover by district in Kenya (FMF 2001). Shortly thereafter four large timber companies resumed clear felling practices in both indigenous and plantation forest tracts. One company, *Timsales*, (partly owned by former President Daniel Arap Moi), continues to run sizeable timber operations in the mountains surrounding the watershed.

By 1997, extraction had dramatically altered the landscape of the UCRN—perhaps 50% of forests in the E. Mau Escarpment had been felled. At the end of the millennium, about 5,000 Ogiek living in intact forest stands were evicted from their homelands both within and beyond the UCRN (FMF 2001). Many were given lands in clear felled areas. At the same time, the closely related Tugen and Kipsigis highlanders, who are for the most part agropastoralists, were invited by the Moi government to settle the region. Tracts of clear felled lands were surveyed by the Ministry of Forests and handed out to the immigrants. This was a strategic geopolitical move. Moi hails from the Tugen ethnicity, and because tribalism still holds considerable influence in Kenyan electoral politics (Weinreb 2001), this was of special consideration. It is now widely accepted that both the Tugen and Kipsigis peoples were encouraged to settle the Nakuru District because Moi was interested in increasing his voting base in this predominantly opposition party area (Nduta, 1999; Daniels and Bassett 2002). Because the Eastern slopes of the Mau Escarpment are generally more fertile and rainfall is plentiful, the former western highlanders were quick to seize the opportunity for resettlement. . In 2003, Moi finally vacated office after 39 years of semi-autocratic rule. Mwai Kibaki, who promised sweeping land reforms in Kenya, succeeded him. Although no formal census has been completed in the area, study participants on average claimed that the demographic makeup of the UCRN was approximately 75-85% Tugen and Kipsigis, with Ogiek peoples making up the remainder.

In response to what they consider to be the colonization of their ancestral homelands, the Ogiek Welfare Council (OWC) a non-governmental advocacy organization operating out of Nakuru, has brought a legal suit against the former Moi government. Three related land claim cases have been filed by the OWC, and although the OWC lost the first phase of legal proceedings, they quickly appealed. Despite Kabaki's appointment of new Judges to hear pending land cases, the OWC suits have not yet been heard in full. Still, the Ogiek remain hopeful that the appeal will be successful.

Nonetheless, the reality of the UCRN stands in stark contrast to the OWC's hopes. The remaining Ogiek living in the forest's margins are currently being evicted, and many have settled with relatives in the UCRN. Relations between the three ethnicities in the UCRN are particularly strained, and for the most part the Ogiek refuse to cooperate or communicate with the Tugen or Kipsigis. Until a final verdict is reached in each of the OWC cases, the Ministry of Forests is reticent to grant formal land tenure to any resident of the UCRN. There remains the limited chance that success in any of the OWC cases could result in the repatriation of Tugen and Kipsigis settlers, although exactly *how* this process might occur remains unclear. Although there have been no recorded instances of ethnic violence in the area, there is constant threat that these tensions could result in physical aggression (Daniels and Bassett 2002; FMF 2001).

This is problematic for projects like SUMAWA-CRSP that hope toimplement conservation measures in the area. In a study of projects implemented in the Lake Nakuru Basin by the World Wildlife Foundation and related non-governmental organizations (NGOs), Daniels and Bassett (2002) concluded that the reluctance of the state apparatus to grant official land rights to residents has resulted in farmers' lack of enthusiasm to engage in long-term conservation measures. In conclusion, Daniels and Bassett (2002) are correct to state that conservation interventions must be designed with the utmost awareness that local actors' reasons for participation in improved natural resource management techniques are "…shaped by the interplay of social, political and ecological dynamics at multiple scales…"

4. MATERIALS AND METHODS

Data collection and analysis for this study consisted of three main components: (1) in-depth interviews with farmers, (2) the collection of soil samples from within farmers' cropped lands, and (3) the assembly of background information gained through meetings with officials from the Kenyan Ministry of Environment and Forests, local NGO'S and documents retrieved from the Kenyan National Archives.

4.1 Farmer Interviews: Data Collection

Fifteen farms were included in the study sample (see Table 1). A series of open-ended discussion questions were used. The remoteness of the study area combined with the limited amount of time allotted for data collection influenced the use of purposive/convenience sampling for the study. Interview participant selection was based on the following criteria: (1) Farmers cultivating on slopes between 5 and 40% within 200 m of a spring, or a first or second order stream were given priority; (2) Farmers representing a diversity of ethnicities, ages and genders. Female-headed farm households were intentionally included in the sample. Although the selected sample may not be representative of the UCRN population, it was chosen to capture the full range of perspectives on the research issues. It was considered important to include several respondents from smaller population sub-groups to explore differences in farm practices that may arise from differences in gender, ethnicity, age and social agency categories. While basic survey forms were prepared for use during the interviews, farmers were encouraged to lead the discussion by deviating from the prepared questions and their order to elaborate on any additional issues/themes they found to be valuable. The basic interview question topics are listed in Table 1.

Table 1 . Examples of general subject questions used to generate discussion during the interview process.

Soils
How are your soils prepared for cropping?
When do you till the soil?
Would you consider your soil to be fertile?
For how may years do you expect to have yields as large as the previous years? How does fertility affect this?
What are the characteristics of a poor soil?
How do your soils function when it is raining?
Does the rain carry away the soil (erosion)? Where and where to?
Forestry
What trees do you have on your shamba?
What are the trees used for?
Is there a relation between the fertility of the soil and the trees?
Is the tree cover in this area declining? The same as Ever? Growing? Why?
Is there a relationship between the trees and the rain?
Is there a relationship between the trees and the river?
Why is it that some communities have chosen not to cut trees along the river?
Are you satisfied with the forests here? Why or Why not?
General
What do you see at the biggest need for farmers in your area?
How do you manage crop residues?
Some people who live down the river say that they think the farming activities in this area are harmful to the river. Would you agree? Why or why not?

In addition to topics covered in Table 1, a number of standard agronomic questions were used to gather information on farmers' agricultural practices. Participants were queried regarding their approach to farm design and layout, their choice of crops and cropping patterns, the agricultural calendar, and the division of labor in on- and off- farm activities. A tour around the farm was made with the participant.

Because of difficulties in interviewing farmers across several ethnicities and language dialects, a local translator (conversant in all languages) was hired and trained to assist during the interview process. Each sentence spoken by the interview participant was translated directly. Of the 15 interviews, 14 were audio recorded for later transcription. Detailed notes were taken during visits and interviews. In most cases, the interviews consisted of discussions and tours of the farm property lasting several hours. When farmers were not averse to spending additional time with the researcher, a participant-observation approach was used to return to the farm and take part in daily agricultural tasks in order to more fully become familiar with the farming system and its functioning. This was done with one half of the farmers.

Sample farmers ranged in age from 22 to 55 years old, with a mean of 38 years. Six were female, of which three were heads of household. Average farm family size was six. This figure includes extended family members (e.g., as defined by grandparents, and/or uncles, aunts and members family related by marriage). Of the 15 respondents, eight were Ogiek, five were Kipsigis, and two were Tugen. None of the interview participants held exclusive title to their lands, although all displayed settlement survey cards provided by the Ministry of Forests.

4.2Farmer Interviews: Analysis

Because significant portions of in the interview data collected during this study were qualitative, grounded theoretical analysis (emergent theory) was employed to analyze much of the data. Following the guidelines set forth by Glasser (1992), generalized themes that arose from the farmers' responses were coded and placed into categories. From this preliminary analysis, a literature review was conducted to provide a theoretical approach and grounding for the categorical information that emerged. This methodology is of considerable importance in cross-cultural studies where the imposition of the researcher's cultural values could impinge upon what is objectively reflected in the participants' statements. Analysis of emic information that emerges from this kind of data analysis can also be useful in the development of natural resource management strategies that seek to account for and integrate the values of local populations.

The information derived from emergent analysis was later compared to 'scientifically' derived information regarding soil and forestry resources. Similar approaches have been used previously in ethnopedological research. According to Barrera and Zinck (2003), research that utilizes integrated approaches to data analysis invariably "mobilizes the relationship between cultural and scientific information in order to elaborate upon natural resource management schemes according to local social, cultural, economic and ecological contexts." The broad themes emerging from the interviews discussed later in this paper are representative of emic categories that signify subjects of importance to the local population in the UCRN.

4.3 Soil Sampling: Data Collection

Soil samples were taken from each farm. A minimum of 15, and as many as 20 soil cores at a depth of 300-350 mm were collected from each farm at random locations across all cultivated fields. These were tabulated with Global Positioning Systems (GPS) coordinates for location and elevation from each farm analyzed. Smaller, intact samples that were taken from horizontal cuts in soil pits were later used to measure bulk density. Extreme care was taken to insure that the cores were not contaminated by any residual carbon sources (remnant roots, or tree debris, etc). Although care was taken not to disturb the cores during transport, the difficult voyage involved in returning from the field inevitably resulted in the fracturing of several cores. In the laboratory, the cores from each farm unit were mixed to obtain a sample representative of the broad scale soil quality of that farm's cropping unit.

4.4 Soil Sampling: Analysis

Textural analysis of the soil samples was done using the hydrometer method. Acidity/alkalinity were measured with a pH meter as outlined by the Tropical Soil Biology and Fertility Program (TSBFP) (Okalebo and Gathua 1993). Percent carbon (% C) was determined by titrate following the guidelines set for the by the TSBFP. Cation Exchange Capacity (CEC) was found by distillation and titrate as outlined by the Kenyan Ministry of Agriculture (Hinga, Mucheana et al. 1980). % Soil Organic Matter (SOM) was determined by calculation based on % C values and the assumption that SOM is 58% C (Okalebo and Gathua 1993). % Nitrogen was calculated by acid digestion as described by the above reference. Total Phosphorous was found utilizing the Ammonium molybdate/Amonium molybdiate vanadate procedure (Hinga, Mucheana et al. 1980). Available P was found using the vanadium yellow method (Okalebo and Gathua 1993). Dry bulk density of the soils was measured as the average mass of oven dry soil (72 hours at 40°C) per unit of the bulk volume of the soil mass in question.

4.5 Statistical analyses

Independent sample t-tests were used to compare soil quality across different categories of farmers. Tests were conducted for each of the soil physical and chemical properties analyzed to see if there was a significant difference in soil parameter values under varied farm management practices or according to farmer self-rating of soil quality and soil erosion problems. Categories examined included farmers utilizing organic soil amendments compared to those using inorganic fertilizers, male compared to female farmers, farmers who expected their soil fertility to decline significantly in five years compared to those expecting no change, and farmers who claimed to experience problems with erosion compared to those who did not. Crop yields are reported as the mean value of those reported by all farmers. Comparisons were made using the Food and Agriculture Statistical Databases (2004).

4.6. Additional data collection

Additional meetings were arranged with the Ogiek Welfare Council and Provincial Forest Officer of the Rift Valley section of the Ministry of Forests. During these interviews, detailed notes were taken. Colonial documents located at the National Archives in Nairobi were also consulted to collect primary information on past forest policy and land use/management in the UCRN. Information gleaned from these sources was used to inform historical and political analyses of the UCRN.

5. RESULTS AND DISCUSSION

With the exception of a few select studies, relatively little is known about the ways in which smallholders' soil management decisions are linked to broad scale environmental features in the uplands of Nakuru District (Omamo et al. 2002). More comprehensive work has been conducted on the western side of the Mau escarpment, where many farmers have participated in agroforestry programs (ICRAF 2004). Extrapolation of the lessons learned by these projects to the E. Mau is problematic as soil, climactic, agronomic and social conditions vary considerably. Consequently, what follows is a detailed analysis of UCRN farming systems in terms of both biophysical and social issues.

5.1 Overview of UCRN cropping systems

Farm production concentrates on maize with a dry bean intercrop. In most cases both seeds are placed in the same hole when planting. Although this eliminates additional labor during the production process, increased competitive stress between the species may lower yield. Farmscapes are patchy, with areas originally planted to maize that yield poorly, lodge or fall victim to pests and disease. *Crysanthamum pyrethrum* flowers are generally cultivated alongside cabbages and other leafy greens. Pyrethrum is harvested and sold to middlemen or directly to representatives of the Kenya Pyrethrum board, where flowers are processed into a biological insecticide for sale on the global market. This product itself is not used in the UCRN, largely due it it's prohibitive cost and high rates of export. Potatoes may be intercropped within the maize/bean fields, although their productivity is insignificant.

Households are usually located up slope. Several species of trees may be encouraged in this area for medicinal and fuel wood purposes, although it should be noted that the numbers are generally small (<15). If the household possesses livestock (on average < 2), they are corralled upslope and grazed on communal lands. Only once a year, and for a week alone, are they permitted to graze within the confines of the cropped land. This is done immediately after harvest is complete and before crop residues are burnt.

Tree seedlings that naturally root on the farm may be encouraged as they can later be sold for fuel or timber. Of the farmers interviewed, 9actually reported *transplanting* seedlings from public lands, forest reserves, or farm boundaries onto their farms in an effort to develop tree crops. A graphical description of the farming system is provided in Figure 3.

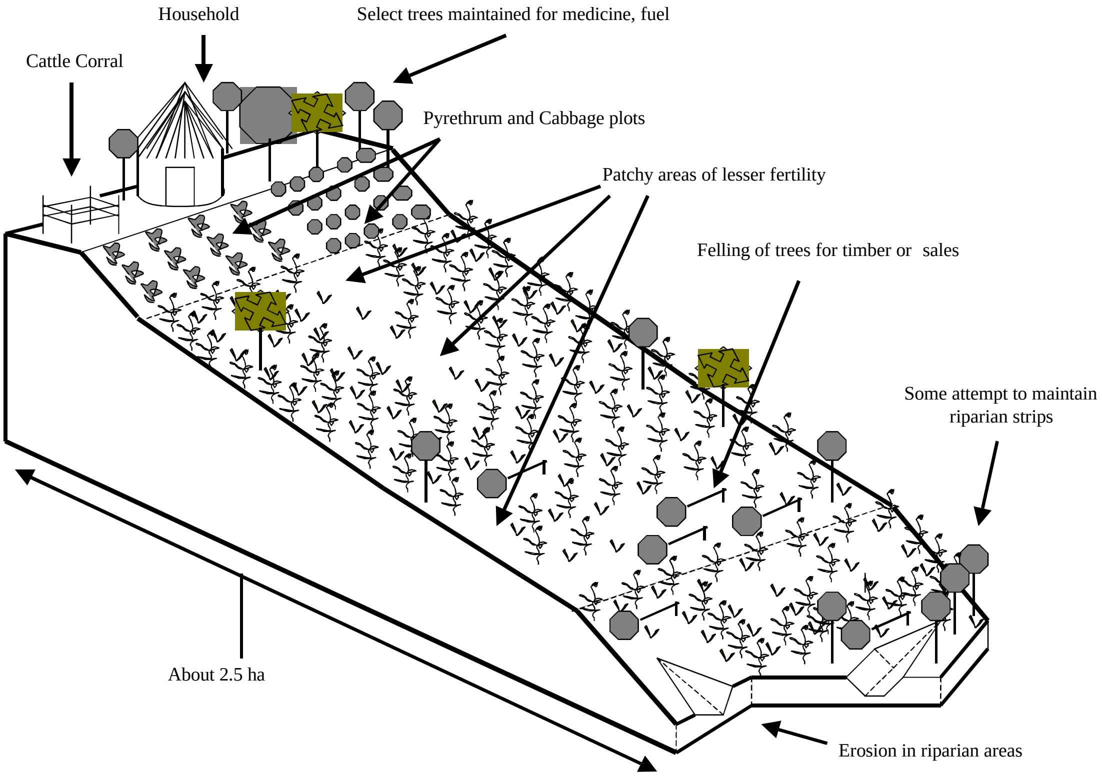

Figure 3. Graphical representation of the UCRN cropping system.

From an agronomic production standpoint, UCRN cropping systems show mixed performance. Figure 4 shows yields for select agricultural commodities in Kenya as a whole verses the average of the study area.

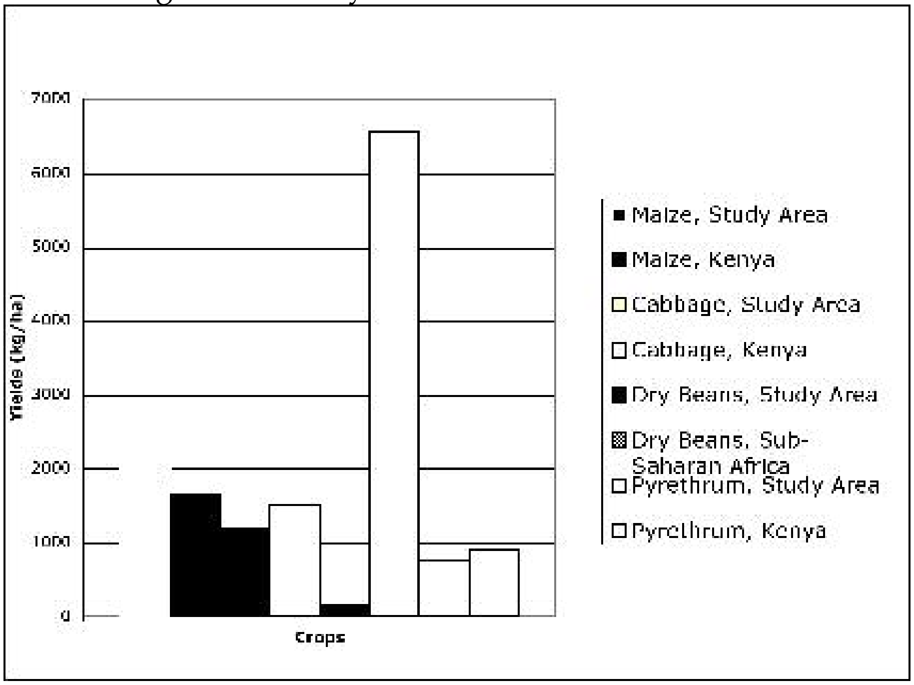

Figure 4. Representative yields for major agricultural products of the UCRN as compared to Kenya and Sub Saharan Africa.

Maize makes up the majority (51%) of yield benefit accrued in the baseline LUS. When compared to Kenya as a whole (• 1647 kg ha year^{-1}), average maize yields in the UCRN (• 2085.7 kg ha year^{-1}) are high[3]. Nonetheless, one must bear in mind that maize production in Kenya is generally considered to be poor, and that in the UCRN, because of the cold and overcast weather, it takes 10 months until farmers harvest their crops. Cabbage production in the UCRN is about 1200 kg ha year^{-1}, much lower than Kenya as a whole (•1647 kg ha year^{-1}). Dry bean production statistics were not available for Kenya, but when compared to SSA as a whole (• 6544 kg ha year^{-1}), production is *extremely* poor (• 142.9 kg ha year$^{-1)}$. This is partially attributable to increased competition for light and nutrient resources due to the dual placement of maize and bean seeds in the same planting holes.[4] Pyrethrum production in the UCRN is also low (• 775 kg ha year^{-1}), although not as dramatic as the discrepancy in dry bean (Kenya's average for pyrethrum production is about 100 kg ha year^{-1} higher). In sum, when examined from the standpoint of potential agronomic performance, UCRN cropping systems are far from optimal but not particularly different from Kenyan averages.

5.1.1 UCRN Farm soils

As mentioned above, the soils in the UCRN are predominantly of volcanic origin. Classified as Mollic Andisols, they are of generally better quality than most African soils. Table 2 reports the qualities of the soil samples taken from the 15 sample farms.

Table 2. Soil characteristics for each farmer's field

Number	Texture	Years Farmed	Bulk Density	PH	Total N (%)	Total P (%)	Available P PPM	CEC (me g/100g)	SOM (%)
1	Sandy Silt Loam	5	0.94	6.20	0.85	0.11	0.002	31.92	5.53
2	Sandy Silt Loam	4	0.95	6.10	0.72	0.05	0.001	37.52	8.41
3	Sandy Silt Loam	9	0.98	6.50	1.50	0.06	0.003	26.88	6.02
4	Sandy Silt Loam	8	0.99	6.70	1.21	0.08	0.002	39.20	7.38
5	Sandy Silt Loam	5	1.01	5.80	1.03	0.07	0.002	36.12	7.22
6	Clay Loam	5	0.93	5.80	0.72	0.02	0.002	29.68	5.53
7	Clay Loam	7	0.98	5.80	1.09	0.10	0.001	37.80	7.14
8	Sandy Silt Loam	10	0.98	6.00	0.91	0.08	0.002	30.52	7.29
9	Sandy Silt Loam	5	0.87	6.40	0.79	0.06	0.001	30.52	6.74
10	Sandy Silt Loam	7	0.96	6.40	0.79	0.06	0.003	36.68	7.38
11	Sandy Silt Loam	8	0.94	6.70	1.33	0.05	0.003	32.20	8.41
12	Sandy Silt Loam	4	0.98	6.20	0.61	0.08	0.002	32.20	6.57
13 †	Clay Loam	3	0.97	7.00	0.91	0.08	0.002	35.56	8.10
13 ‡	Sandy Silt Loam	3	0.89	7.00	0.84	0.08	0.001	41.44	8.50
14	Clay Loam	4.5	1.02	6.30	0.80	0.07	0.002	34.72	6.33
15	Sandy Silt Loam	12	0.92	6.20	0.78	0.05	0.002	36.68	6.74

†=Soils uphill, fertilized organically

‡ =Soils close to the river, ferttilized iorganically

Unlike Western Kenya, the UNCR sample soils are not highly acidic. With pH ranging from 5.8 to 7.7, the sample soil pH levels are considered optimum for crop growth. Bulk density, (0.87 to 1.02 gcm^{-3}) and Cation Exchange Capacity are generally good for agricultural production. Because of transport difficulties in getting soil cores to the

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[3] Yield figures not pertaining specifically to the UCRN were calculated using the Food and Agriculture Organization Statistic al Databases: http://faostat.fao.org/faostat/form?collection=Production.Crops.Primary&Domain=Production&servlet=1&hasbulk=0&version=ext&language=EN

[4] It is important to note that the dry bean statistics listed above for SSA are for monocultural production. Nonetheless, even if these figures are modified (for example reduced by one-half or even two-thirds) to represent lowered intercrop-seeding rates, bean production in the UCRN still performs *very* poorly.

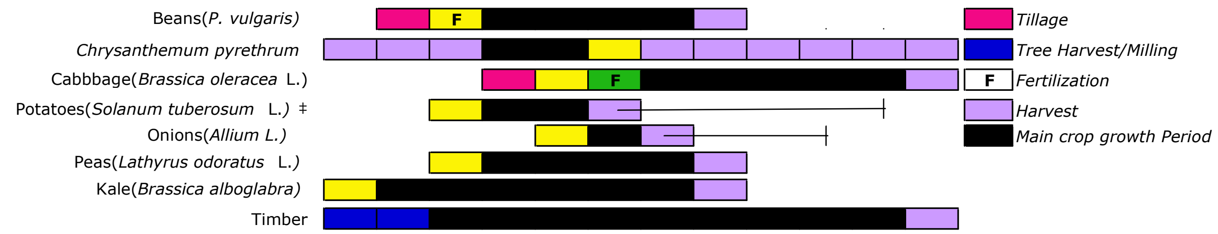
laboratory in time to determine available N content, only total N (%) is shown. Although this N is generally not available for crop production when considered on an immediate time scale, the percentages shown (0.78-1.79 %) are not indicative of any major long-term deficiencies. Nonetheless, it should be noted that limitations of other nutrients, for example P, could alter the long term cycling and availability of N to the agricultural system. Because UNCR soils were under forest cover for much of their modern geologic history, they have a rather high soil organic matter content (5.53-8.50 %). which can be taken as an indicator of potentially high fertility. Total P (0.02-0.11 %) exists in stark contrast to available P levels which ranging from 0.001-0.003 ppm. The sample soil analysis points to P limitation as a major constraining factor for crop growth.

P deficiency can be visually corroborated by noting the purple-blue hue that stains maize leaves and stalks in the UCRN. These colors, which are a result of an accumulation of anthocyanins, occur when crop nutrient uptake is poor and are a primary indicator of P deficiency (Haven et al. 1999). The effects on crop growth include disruptions in internal crop transfer of energy needed to maintain plant metabolic processes. P deficiency also entails interruptions in the biochemical processes upon which DNA is synthesized. Deepened coloration of maize leaves also impacts crop productivity through lowered photosynthetic rates that can in turn reduce crop to tillering and the development of comprehensive root systems. The high incidence of maize lodging in the study area could in some part be attributed to these processes. Phosphorous deficiency is not the only limitation when considering agricultural production in the UCRN. The high rates reported by farmers of pest incursions (aphids, cut worms and maize stem boarers in particular), limitations in labor availability, and climactic conditions are also noteworthy factors constraining yields.

5.1.2 The UCRN Agricultural calendar

Table three depicts the agricultural calendar in the UCRN, based on the 15 sample farms. Although additional annual crops are cultivated, maize, beans, cabbage and pyrethrum are the primary agricultural commodities. The three former ones three are at least partially and sometimes totally consumed by the household, with about ≈1/3 being sold. Trees that have rooted or are planted on farm acres may also be harvested, although this occurs infrequently.

Table 3. Planting, growth and harvesting schedule for common annual crops in the upper Njoro watershed.†



Crop	J	F	M	A	M	J	J	A	S	O	N	D
Maize (*Zea Mays*)	🟪	🟥	🟨 F	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛
Beans(*P. vulgaris*)		🟥	🟨 F	⬛	⬛	⬛	⬛	🟪				
Chrysanthemum pyrethrum	🟪	🟪	🟪	⬛	⬛	🟨	🟪	🟪	🟪	🟪	🟪	🟪
Cabbbage(*Brassica oleracea* L.)				🟥	🟨	🟩 F	⬛	⬛	⬛	⬛	⬛	🟪
Potatoes(*Solanum tuberosum* L.) ‡			🟨	⬛	⬛	🟪	—	—	—	—	—	
Onions(*Allium L.)*					🟨	⬛	🟪	—	—	—		
Peas(*Lathyrus odoratus* L.*)*			🟨	⬛	⬛	⬛	⬛	🟪				
Kale(*Brassica alboglabra)*	🟨	⬛	⬛	⬛	⬛	⬛	⬛	🟪				
Timber	🟦	🟦	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	⬛	🟪

Key	
🟩	*Transplanting*
🟨	*Planting*
🟥	*Tillage*
🟦	*Tree Harvest/Milling*
F	*Fertilization*
🟪	*Harvest*
⬛	*Main crop growth Period*

†=Crops are generally planted in the spring (with the exception of kale) and harvested sometime thereafter.

‡=Potatoes are usually planted every few years. Aside from this, they are harvested anytime between June-November. Seed potatoes are left in the ground in intermittant years (not all are harvested) to allow regrowth.

•=Growth times are shown in black. Full bulbs are removed only from July to October.

Slow crop growth (especially in maize) could likely be attributed to a combination of influences including the sub-optimal climate, reduced photosynthesis due to P deficiency which in turn entails hampered root development and uptake of nutrients, the choice of poor maize varieties, increased competition due to crowded planting conditions (as up to 3 maize and two bean seeds may be sown in each hole prepared for planting), and inordinate planting depth of • 160 mm. Farmers explained that the high seeding rates were a form of insurance because one or more seeds may fail to germinate. The deep placement of seeds is a result of the depth at which planting holes are dug manually with a hoe.

Retarded growth factors are particularly significant because of the high volumes of rainfall that can be experienced shortly after planting and tillage. 7 of farmers reported a significant loss of maize seedlings because rainstorms washed away their emerging crop. Quicker growth rates and the rapid establishment of root systems in particular would help to stabilize the crop against these effects. Another five percent of farmers reported reduced germination rates due too excessive soil saturation or movement during heavy storm events.

Cabbage and other Brassicas may be grown in separate plots of land. *Chrysanthemum pyrethrum* is also cultivated in separate plots. Because pyrethrum is a perennial species, after the second season it can be harvested for about three years before replanting is required. Flowers are picked almost year round, dried and stored for sale in Nakuru. Other crops (onions, potatoes, kale, etc.) are cultivated in smaller 'home gardens' and are generally poorly yielding and used for household consumption only.

Labor inputs to the cropping system occur mainly during tillage months, and planting, harvest and weeding periods. The latter occurs generally twice during the crop growth cycle, most often in June and July as well as September-October-November, although the actual timing is the producer's decision. All agricultural tasks are preformed by hand. If hired labor can be afforded at these times, it is not uncommon for the farmer to employ one to two people to assist with this process. Post harvest activities are almost entirely preformed by the farm-household unit.

Additionally, timber may be harvested (although not yearly) from UCRN production systems. The majority of farmers in the study sample area encourage tree seedlings that have rooted on their acres, although the number of trees is generally small (<25). Six farmers actually transplanted naturally occurring seedlings found in riparian or forest margins to their acres. When mature, these trees will be felled for fuel wood, pole or timber production.

5.1.3 Non-crop income sources

Off farm work is difficult to acquire in the UCRN. Weeding periods provide perhaps the most recognized source of off-farm income, although this opportunity occurs only twice a year. Though payment is generally poor[5], there is a high degree of competition for weeding positions. Migration to Nakuru and even Nairobi by male family members to look for work is not uncommon, although few farmers interviewed reported that employment had successfully been attained. Other UCRN sample

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[5] 100 2003 Kenya Shillings for a full day's work; 75 Ksh = 1 USD, 2003.

households may be engaged in beekeeping and limited livestock production activities in order to obtain additional income. Although returns for honey sales may be great, harvests are irregular and unreliable. Livestock products are primarily consumed by the household.

Far more common is non-farm income derived from fuel and wood harvesting as practiced in the margins of remnant forests and in riparian zones. If converted to charcoal and transported to Njoro by bike, one sack (about 40 kg) can be sold for 350 2003 Ksh during the wet season. The same volume is sold for the equivalent of 100-150 2003 Ksh in the dry season. Sample farmers admitting regular engagement in these activities (•50%) universally stated that fuel wood collection and sales, if practiced by young males (for whom the opportunity cost of labor is < adults), represents a viable activity that can augment incomes otherwise reliant solely on farm produce. Earnings for transport and sale of fuel wood that has not been converted to charcoal are generally 1/2 of those associated with charcoal, although returns are more immediate. These activities are of particular concern for watershed managers interested in the conservation of upland forests.

5.2 Soil management

Table 4 describes farmers' soil fertility management techniques and perception of future fertility. It is significant to note that inputs intended to boost cropping system fertility are generally low, with several farmers applying no amendments at all. In only one case was animal manure used in significant quantities (number 13, 180 kg ha^{-1}), but here the farmer attributed this to a single year in which he was able to access additional manure from a neighbor with which he wished to experiment.

Table 4. [illegible]

Farmer	Soil Amendment (kg ha^{-1})	Number of Applications yr^{-1}	Application method	[illegible]	Future Fertility	Best Fertility strategy
1	20	2	[illegible]	2	3	Additional inorganic fertilizers, cattle manure ‡
2	[illegible]	1	Placed in furrow at planting	[illegible]	[illegible]	[illegible]
3	18	1	Placed in furrow at planting	4	2	Additional inorganic fertilizers
4	[illegible]	1	Placed in furrow at planting	[illegible]	10	[illegible]
5	20	1	Placed in furrow at planting	2	2	Additional inorganic fertilizers
6	25	1	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	1	Placed in furrow at planting	[illegible]	2	Manure
8	None			10	[illegible]	[illegible]
9	None			2	2	[illegible]
10	None			5	[illegible]	[illegible]
11	10	1	[illegible]	4	[illegible]	Manure ‡
12	10	1	Placed in furrow at planting	[illegible]	[illegible]	Mechanized ploughing
13	[illegible]	1	[illegible]	4-5	2	Additional inorganic fertilizers
14	None			1	[illegible]	Additional inorganic fertilizers
15	18	1	[illegible]	12	2	[illegible]

[illegible]

However, his yields for that season were not significantly different than others and he discontinued the practice as it was "...just too hard to work like that." Because the collection, transport and application of manure is laborious, most farmers described it as being economically unviable. This is the case even with manure that is heaped in cattle corrals near the household.

Inorganic amendments are often applied to UCRN cropping systems, although in quantities so low they are unlikely to stimulate any noticeable yield response. All but one farmer applying inorganic fertilizers placed them either before or during seed sowing. Under such conditions, there is decreased potential for fertilizer uptake as nutrients are in less demand during this period of the crop's life cycle. Nitrogenous based fertilizer use efficiency in UCRN cropping systems, like much of Africa, is thus likely to be low as P deficiency can interfere with crop N uptake (Krupnik et al. 2004-In press). Few farmers appeared aware of these timing issues, although it should be noted that given the costs of these applications, many seem to be doing the best that they can given the limited availability and high cost of fertilizers. Murage et al. (2000) demonstrated that, in lower elevation areas of Nakuru District, that farmers will, if possible, choose to sustain the natural resource base by devoting economic resources to fertility maintenance. The constraining factor in fertilizer application is usually economic, and in the UCRN, costs are prohibitive. A single kilogram of Monoammonium or Diammonium Phosphate in 2003 costs about 25-50 Ksh, 0.33-0.66 USD (same year). The application of 75 kg ha^{-1} $year^{-1}$, which is woefully in adequate, would cost about 24.75-49.5 2003 USD kg ha^{-1} year $^{-1}$. This is a significant capital cost in a country where 62% of the population subsisted on less than 2 USD per day in 1993 (WRI 2004). As in most of SSA, farmers' lack of disposable income to purchase these inputs precludes their widespread use (Vanlauwe, Sanginag et al. 2004-In Press).

Interestingly, farmers' predictions of future fertility contrast with agronomic assessment. Although P is limiting in the sample of UCRN soils, it is possible that current average yields could be maintained given the soil fertility characteristics of the sample farms for quite some time (perhaps >15 years as based on estimates of the performance of maize cropping systems in similar soils). Nonetheless, all farmers reported shorter time horizons when queried about the ability of their soils to maintain current harvests. Responses ranged from 1 to 10 years, with a mean of 3.7. This is likely due to farmers' already significant dissatisfaction with low yields and the extended interlude between planting and harvest. One explained that "The soil may first be very good here but look, my crop is now bad and it is going to be completely bad in about three years. Then I will have to do something else." There also remains the distinct possibility that farmers have simply not adjusted to the soils in the study area, and that past experiences of farming on even poorer soils have influenced their short predictions. In the case of the Ogiek, who formerly led a subsistence lifestyle based on hunting and gathering, their relative inexperience in larger scale agricultural production may influence their prediction of quick fertility declines. Because best management techniques arising from traditional agriculture tend to be place specific, developing in response to unique cultural and ecological influences (Altieri 2004), it is simply too early for farmers to have evolved detailed knowledge of UCRN cropping systems. When asked about their plans for correcting fertility decline, two farmers admitted they had not considered a strategy

Four farmers reported that they would apply additional inorganic fertilizers, although they could not explain how they might afford the costs. Others explained that they would attempt to combine amendments of synthetic fertilizer and manure. If additional land and income were available, they responded that they would fallow portions of their croplands in order to restore fertility. Nonetheless, average fallow time planned was < 2 years, which is generally inadequate to re-supply any significant measure of soil fertility.

The use of pasture and fallow techniques therefore appears to be a rarely preferred technique for the upkeep of soil fertility among the sample farmers, with the sole exception of one Ogiek woman whose late husband championed the technique. The lack of interest in pastoral fallows can be attributed to the expensive opportunity cost associated with taking land out of production. A Tugen man explained that " Using the fallow is very expensive—I mean it does not cost anything to do it, but there is no crop then. So one has to be able to have money for this time, and this is very difficult. So I can not say, perhaps I will do it but I can not be sure now." Finally, one farmer said that they would attempt to incorporate crop residues into the soil. "If I can, I will put back the maize wasted after the harvest into the soil. It is more work, but maybe over some years it will make the soil better for those crops."

From a long-term fertility standpoint, management techniques inclusive of the application of organic amendments (manure, crop residue) be they through fallows of direct application to soils are desirable as these materials increase SOM content and thus improve soil structure and water retention while simultaneously reducing runoff rates. These approaches are encouraging when considered from a watershed conservation standpoint, although it may take many years of fallow before a significant level of fertility is restored in the agronomic sense.

5.3 **Soil quality differences**

There was no statistically significant difference in UCRN soils as related to the management techniques summarized in Table 4. This is not necessarily surprising given that none of the farms had been producing in excess of 12 years. It is questionable whether major differences in soil quality could develop in such a short time, particularly for soils that share a somewhat uniform forest history. Sample sizes were also small, so the capability of statistical tests to identify variability in the data is also reduced. Finally, for optimal sampling of UCRN soils to occur, soil cores should be take place taken over a longer time span, rather than the 'snap shot' nature of these samples.

Nonetheless, due to the difficulty encountered in field access, single sample collection was all that was possible. It is also important to note that despite the lack of statistical evidence for differences among farmers reporting their soils as stable or eroding, these tests do not necessarily mean that these processes are not occurring. Specifically, the t-test on erosion examined potential differences in soils based on *farmer perception*. But because erosion processes (with the exception of mass wasting events or serious rill erosion) are usually slow, diffuse and occur over a long period of time, they often go un-noticed and thus have been referred to as "invisible." (Swallow, Garrity et al. 2001). Although beyond the scope of this paper, research is in progress aimed to develop of a model predictive of erosion from smallholder UCRN farms. Finally, further statistical analysis showed no clear patterns in agricultural 'best management' practices and income, age, gender or ethnicity. A larger sample size may be able to detect generalized trends around these issues.

5.4 Farmer perceptions: Emergent themes

The rise of agroecology as a scientific discipline has heightened the awareness that researchers must understand the totality of the details that drive natural resource management practices (Altieri 2004; Uphoff 2001). This "bottom up" approach to research inevitably considers farmers' autochthonous knowledge of the area in question (Richards 1985). Nonetheless, some scholars have postulated that the dichotomy between scientific and 'indigenous' knowledge should be discarded on the epistemological grounds that the dichotomy inadvertently 2labels local knowledge as 'closed' and 'static;' conversely, scientific knowledge is viewed as objective, holistic and analytical (Agrawal 1995). Agroecological approaches have sought to overturn this phenomenon by viewing 'indigenous' knowledge as a grounded and appropriate source of inspiration that can be utilized to inform and augment scientific studies aimed at improved resource management (Altieri 2002). The relationship is depicted in figure five.

This approach allows for multiple understandings and applications of "knowledge" and thus is highly dynamic (Oudwater and Martin 2003). However, it must be understood that local perceptions of environmental processes can at times be inaccurate. Without scientific input, local knowledge systems may not be able to cope with changing environmental circumstances (Barrios and Trejo 2003), and this can result in ecological degradation beyond the point at which environmental services can be provided. In sum, by matching the complexities of biophysical characteristics of these upland agroecosystems with farmer perception and agricultural practices, it becomes possible to better develop and implement sustainable improvements in these farming systems (Gleissman 1981; Hecht 1990; Fanzel and Sherr 2002; Grossman 2003). Using grounded theoretical analysis, the following categories emerged as resource issues of importance to UCRN sample farmers, and will be important in merging scientific knowledge with farmers' perceptions of issues that impact the provision of watershed environmental services.

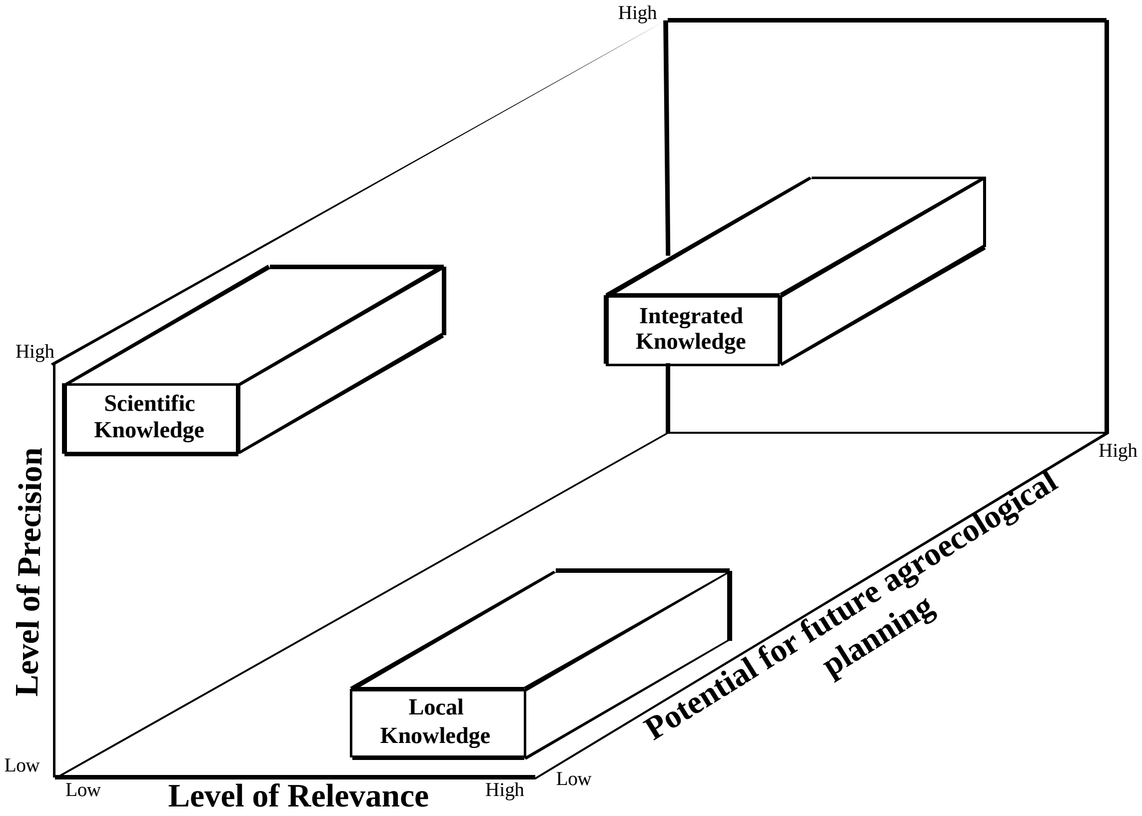

Figure 5. A conceptual representation of the interactions between scientific and local knowledge as pertaining to agroecological systems. Integration of both scientific and local knowledge leads to heightened potential for successful future agroecological planning. ***Adapted from Barrios and Trego (2003).***

5.4.1 Perceptions of soils

Because the predominant factors impacting soil erosion in tropical forests are the conversion of these areas to agricultural land uses (NRC 1993), there is concern that agricultural practices in the upper Njoro watershed will eventually result in a heightened level of land degradation. It is therefore instructive to further examine farmers' perceptions of soil resources so that conservation planners can more efficiently communicate with farmers regarding the preservation of these resources (Pawluk, Samdor et al. 1992; Warkemtin 1999).

5.4.2 Sub-standard soils

As explained by Barrera and Zenck (2003) in their review of global ethnopedological studies, soil color was strongly stated by UCRN sample farmers as an indicator of fertility. This phenomenon occurred across all age, gender and ethnic categories, and is not entirely surprising given the eye-catching, bright red-staining that occurs with the high degree of leaching, prevalence of iron oxides, and acidity that is associated with many tropical soils. Almost uniformly, farmers explained that red soils were of meager quality. One Tugen man, who had previously farmed the poorer soils of Western Kenya, explained that he could identify patches of infertility in his fields based upon soil color. "Where the soil is red I know it is bad because it is like before I came here. In these places I apply more fertilizers." Another farmer explained that, "Red soil is bad, this is where the crops do not do as well. The red soil steals the harvest from the crop."

Other signs of poor soil quality included those displaying visual signs of erosion (small rills and gullies). When asked what factors make a soil more erodeable, farmers focused their answers solely on extensive land management systems unrelated to annual cropping by implying that clear felling of trees and excessive grazing were the primary influences on soil erosion. Specifically, trees were identified as important in the restriction of erosion processes due to their ability to intercept and thus restrict high velocity rainfall from splashing the soil surface. A number of farmers volunteered their opinions regarding local corrective measures to restrict erosion processes. Responses included the planting of perennial Napier grass strips along slope contour to the digging of silt trap trenches across the land. Despite universal acknowledgement of these techniques only one farmer actually employed them, and these structures were in a state of disrepair.

Although most farmers acknowledged the importance of trees in erosion control, only two stated that they were interested in using them for this purpose. One of these farmers explained that "Trees hold onto the soil because of their roots. I would plant trees along the trenches I dig if I could—I do not think it would take up too much space." When queried regarding the possible increased competition for soil and sunlight between trees and annual crops, the farmer responded "…if I prune them, there is no problem." The other farmer stated " I will be planting banana suckers to make trees near to the river, at the bottom of my shamba. These trees will prevent the erosion." Despite these comments, actual employment of these methods is rare. When asked why others did not use the practices, these farmers replied that other cultivators "…just do not know about them or do not care."

All farmers reported specific portions of their land where crop yield was poor. In each case this was attributed to the soil being more 'tired, lazy or exhausted' than in other areas. Interestingly, one farmer commented that "downhill the soil is poor, uphill the soil is worse." This is generally true in landscapes suffering erosion processes as gravity moves nutrient rich topsoils down hill where they can collect in depressions or on flat areas. If this occurs, the capacity of down slope areas to produce is increased in comparison to the upslope where the A horizon has been reduced. The soils data collected from his farm corroborated his explanation. Upslope SOM and total N was 6.57% and 0.61%, respectively. Down slope, SOM was 8.1% and total N was 0.91%. Both high rankings are indicative of the potential for increased fertility in down-slope areas. Further studies of farm systems in the UCRN should concentrate on this perception as it could signify a possible area of concern for farmers that can be matched with the introduction of conservation oriented management techniques.

5.4.3 Good soils and their relation to trees

Many farmers commented on the qualities of good soils in tandem with poor ones. Again, soil color was taken as a primary indicator of quality and fertility: "Black soils have more energy than red ones. Because of this, the black soil becomes fertile in itself." Organic matter content was also linked to soil quality, and was often correlated with arbor cover. "If the farmer is good on his farm, and he weeds carefully and feeds back the weeds to the soil, the weeds will rot and then the soil becomes good. Trees shedding of their leaves also helps the soil a little in the same way." Others noted adverse effects of tree-plant competition and its impact on crop yields "The farmer who prunes his trees should have no problem with the crops near the trees. But lazy farmers will lose their crops, and sometimes it is difficult to have time to cut back the trees." Another commented that "…some trees may take from the soil if planted close to the maize." This was echoed by another farmer who explained "…when planted closely to the maize, the trees will make it so the maize can not grow." Importantly, only one Tugen farmer had thought of using tree leaf litter as a green manure for fertility enhancement. He was aware of this technique due to previous employment on a large farm in Western Kenya where cut and carry fodder/green manure methods were practiced. Nonetheless, he was averse to using the method on his UCRN farm because labor was viewed as too constraining.

5.4.4 Perceptions of forestry management and watershed services

What follows is a discussion of farmer's perception and management of tree and forest resources in relation to broad scale hydrological cycles. Discussions centered mainly around two general geographical categories: riparian zone (RZ) vegetation and the state owned forest/plantation reserves located ≈1-3 km uphill from the study area.

5.5 Forest Inventory

Farmers identified numerous tree species that occur both on their acres and in neighboring RZ's and forests. The complexities of these understandings in reviewed in Table 5.

Table 5. Some commonly managed trees in the upper Njoro watershed.

Scientific name	Frequency †	Native?	Uses	Additional comments
Hagenia abyssinica	R	Yes	F, M	
Morus alba	R	Yes	T, F, FR	Propigated vegetatively.
Zanthoxylem gilletti (Fagara macrophylla)	R	Yes	T, F,M	Timber and fuel. The bark may be used in treating coughs and the common cold.
Cussonia spicat	C	Yes	M	A common riparian species.
Eculea divinorum	C	Yes	T,F,TH,M	
Croton macrostachyus	C	Yes	TH, M	
Ficus thonningii (F. eriocarpa)	C	Yes	RO,M	Though not utilized in the Njoro river area, the leaves can be used as a green manure or mulch.
Croton macrostachyus	C	Yes	TH,M	
Grevillea robusta	C	No	T,F,CH	Although not practiced in the Njoro river area, the leaves can be used as a fodder source.
Schinus molle	C	No	F,BF,M	
Teclea simplicifolia	C	Yes	T,CH,M	A riparian species.
Warburgia ugandensis (W. salutaris)	C	Yes	F,M	
Dombeya goetzenni	C	Yes	BF,F,T	Also bow/arrow construction.
Eucalyptus globulus	C	No	T,F	
Podocarpus falcatus (P. gracilior)	C	Yes	T,F,TH	Beehives are often placed in the trees branches.
Cupressus lusitanica	EC	No	T,F	A former plantation species.
Juniperus procera	EC	Yes	T,BH,F	Sometimes planted to denote property lines. Was used by the British to make pencils.
Olea europaea subsp. africana	EC	Yes	T,F,BF,M	A prized on-farm species.
Pinus patula	EC	No	LI, T,TH, F	Logged industrially for paper pulp.
Polyscias fulva (P. kikuyuensis, P. ferruginea)	EC	Yes	BH,	Though not utilized in the Njoro river area, the leaves can be used as a green manure or mulch.
Prunus Africana (Pygeum africanum)	EC	Yes	T,F,M	

†= *Categories based on respondants' impressions of tree frequency in the upper watershed.*
R = *Rare*
C= *Common*
EC = *Extremely common*
F=*Fuel*
M=*Medicinal Uses*
T=*Timber*
TH=*Tool handles*
RO=*Rope Fabrication*
B=*Bee fodder*
BH=*Beehive Fabrication*
LI=*Timber (industrial)*
FR=*Edible fruits*
CH=*Charcoal Production*

The majority of farmers explained that the primary attraction of local forest resources was to supply timber and fuel wood. Four men noted the medicinal potential of trees, although they did not explain their specific uses. Women were generally capable of describing in detail the medicinal uses of local tree species. Only Ogiek peoples stated the need to conserve tree resources because they were "beautiful" and a source of fodder for bees. This is not surprising as the Ogiek are known for their apicultural practices and conservation ethic (Ogot 1978). Importantly, three species [Polyscias fulva (P. kikuyuensis, P. ferruginea) and Ficus thonningii (F. eriocarpa), *Grevillea robusta*] can be used as a green manure/fodder although only one farmer explained that he was aware of this potential. Each of these species are classified as common or extremely common, and thus hold some potential for further domestication and agronomic use.

Trees are also important when considered in a social context. Of all farmers interviewed, 86% responded that if they were able to plant additional trees on their farm, they would choose to place them around the parameter of their land. Given the contentiousness of land use and title in the UCRN, this is not entirely surprising. Historically, under customary law in parts of Kenya, the planting of trees along boundary lines has been used to demark the limits of a farmer's property. Under the colonial administration, this practice was given a sense of legitimacy as forest officers on occasion recognized tree-lined boundaries. Postcolonial land reform in Kenya reduced the legitimacy of these practices for proving small holders' right of access to land (Dewees 1995). Today, customary law holds little sway upon the state's legal definitions of land tenure and property. Nonetheless, there exists a residual effect enforcing the cultural legitimacy boundary plantings, and this is reflected in farmers' near universal desire to establish trees along the parameter of their farms. Fortmann (1988) explains that for East African persons, and those lacking formal title in particular, that planting trees on lands is often perceived as establishment of the right to access, produce, and to collect materials from the trees, even if control of the land upon which plantings are located is relinquished. Thus, in the UCRN, farmers are making use of somewhat defunct customary law in an effort to lay claim to lands upon which they have no legal tenure. "If I plant the trees along the shamba, then it will be known that this place is mine, and that I will farm here in the future, " concluded one Tugen farmer.

Thus, the claim put forth by Daniels and Bassett (2002) that land insecurity could hamper conservation efforts in the River Njoro Watershed could in the case of the UCRN turn out to be not entirely correct. When farmers actively seek to legitimize their status as holders of land resources, conservation interventions based on tree planting may hold particular promise. Nonetheless, planners must consider the social ramifications of promoting tree establishment in an area marred by ethnic land conflict, where the legality of land holdings is still in question. Additional plantings could heighten the potential for inter-ethnic violence if recent settlers from Western Kenya are legally mandated to vacate UCRN lands. Farmers' perceived claim to the land as legitimate after making the investment to establish trees could be problematic, underscoring the need for planners to understand the social meanings of trees in relation to customary law and land tenure issues (Fortmann 1988).

5.5.1 Forests and their relation to climate and hydrologic patterns

Farmers strongly correlated trees with the maintainance of climatic patterns. Remnant stands of primary forests were attributed with "collection" of moisture from the air. "The trees attract rain to these lands because they stop the wind from flowing. See, like over there." Pointing to a large bank of rain clouds positioned over the western edge of the Mau Escarpment, the farmer continued, "The forest will now make the rain fall from the sky because the forest has stopped the cloud from moving." RZ trees were associated with the continued functioning of stream flow because they shade river waters from the intensity of the summer sun. "This means that the in the dry season, when it is hot, the trees will keep the river from going up and away into the air. They keep the river from drying." This interviewee was an older Ogiek woman who had resided in the region for her entire life. "I remember that even the British set large reserves along the river Njoro and the side streams. In these places you could not go to cut trees or to cultivate because it would make the water to be lost." Referring to the Little Shuru Tributary she continued, "You know, in the last few years all of the rivers in the area have dried but this one and this is because there are many trees left here. We had a lot of shade in on each side of the river for a long distance." She concluded by lamenting that "Now, they (*referring to Tugen and Kipsigis settlers—ed.)* are moving into this area, cutting the trees and planting cabbage, so I do not know about the future of the river."

5.5.2 Income generation: Fuel wood sales

Commentary by Ogiek blaming the incoming Tugen and Kipsigis settlers for environmental destruction and tree clearing are not uncommon in the UCRN. Several interviewees echoed that "We Ogiek do not take the trees because we have lived in and love the forests." Nonetheless, 37% of Ogiek interviewees candidly admitted to participation in extensive forest felling and clearing practices in order to generate marketable fuel wood stocks. They explained that despite the Ogiek love of forests, and the understanding that these features provide important environmental services like the provision of rainfall, that "…people have the need to get the money that can come from cutting and making charcoal. If it is bad for the river we have no choice, and there is little option open for us. We have to get what we can because much of our land has been taken away…" Another Ogiek man explained that "…some people have the need to get a lot of money so they will go to the river and cut the trees and then sell the trees once they have converted them to charcoal or even if they just sell it as wood in Nakuru. There is no other choice if you have the need of getting the money. This surely impacts the river, but when people have the need of money, there is nothing here stopping them."

Another farmer estimated that approximately 50% (inclusive of all ethnicities) of UCRN households were involved in charcoal production activities during some part of the year. Cutting sometimes occurs at night to avoid the purview of the few officers employed by the Ministry of Forests to keep watch over remnant forest and plantation stands. "These people destroy the river because they cut right up to it and burn it there for charcoal. Then they cultivate this land, right there, and it is a very bad problem." Such grievances where echoed by other Ogiek farmers who explained that "the water has been destroyed. When the trees are cut there by the river for making charcoal, or even for poles, this can be very bad. We have trees by the river, it can prevent the soil from being washed into the river and away from the shambas. But look now, every day there are fewer trees by the river."

All interviewees unanimously denounced RZ clearing activities both on and off their farms as detrimental to soil and river quality. Nonetheless, on many respondents' farms, RZ damage and clearing was clearly visible approaching the river's edge. Only a minority retained > a 1 m buffer of vegetation between cropped lands and the river. There is also additional evidence suggesting that little attention was paid to riparian buffer strips by survey teams from the Ministry of Forests when UCRN lands were zoned settlement after clear felling had occurred (PFO *pers. comm.* 2003). A younger Kipsigis farmer who had resided in t he UCRN for five years explained, "…most of the people living here, near the river, they do not keep the trees along it. They will tell you that they do, because they feel guilty. But there is too much of a need for that land and for the money from the wood, and because the crops are not good, there is the need of more space to cultivate. So now you see, this land is becoming for the crops, not for the trees."

5.4.4 Perception of impacts on downriver populations

When explicitly asked if both farming and RZ activities were harmful to the river and downstream residents, responses ranged from those centered on water quality to those embedded in political and ethnic tensions. For example, a Kipsigis man commented that "Most of those who say that we damage the river here by farming, these people are from different tribes. These people they do not like us because they were not given land here like we were, so they set about to lie about us. Some people want to see us moved so they can come and occupy this land, but what am I doing that is different from them? Still, it can be true that if the riverbanks are cleared it can be bad for the river, and there can be destruction. But what I do here is not different from what those people would do. It is no different." Interestingly, several farmers commented that they were not to blame for the majority of the environmental destruction in the watershed. While they still agreed that clearing RZ and upland remnant trees was harmful to watershed hydrology, they explained that *Timsales*, the logging company partly owned by former President Moi, was in fact responsible for impaired watershed health. A Tugen man contended that "…it is the government and the timber companies that have been doing all the cutting. I am just a farmer. All I can do is take what remains, but it is these people who took away from here truckloads of trees." He concluded by emphatically stating that "Since they have been taking the trees here, the rainfall has declined and the air has gone dry. Because of this, we have no better option than to take what trees may be left, because the crops may be bad. But it is not the farmer who did most of the taking (of trees)."

Such comments are important in that they implore future research in the UCRN from a more strictly political-ecological approach to the question: Do the diffuse actions of many small landholders engaged in forest extraction and RZ clearing outweigh the concentrated industrial logging activities more than 1 km from riparian boundaries? Only continued analysis can determine the extent to which each land use system impacts the watershed as a whole. Nonetheless, one point remains clear: the large scale and unchecked colonization of clear felled lands on slope and close to RZ's entails the heightened potential for detrimental environmental ramifications. It is therefore instructive to conclude this enquiry by noting the 'gaps' between 'scientific' and 'local' knowledge as highlighted in this analysis. A brief explanation of these issues and the potential for future research in the UCRN is highlighted in the final part of this paper.

5. CONCLUSION AND IMPLICATIONS FOR FUTURE RESEARCH

In contrast to the formerly popular "green revolution" modus operandi, there exists no 'pre packaged' technology that can automatically augment natural resource management (Barrett et al. 2002). This is because improved natural resource management (INRM) is informed by a multitude of influences including historical, socio-economic, and biophysical considerations. It should now be clear for development planners considering technological interventions aimed at improved soil fertility, forestry management and watershed functioning that it is useful to be aware of farmers' perceptions of these conditions. Moreover, interventions designed to be applicable to the local populations' understanding of resource issues are more likely to be adopted (Altieri 2002; Altieri 1995). These considerations are especially true in the introduction of INRM interventions that are knowledge as opposed to input intensive, for example improved nutrient management strategies (synchronized timing/placement of fertilizers and crop need), crop rotations, improved fallows, erosion control and agroforestry techniques. Figure 6 summarizes the complexity of influences that imply 'gaps' in 'local' and 'scientific' knowledge as pertaining to the development of INRM in the context of the UCRN.

This study focused on farmer perceptions centered on several basic themes. For example, there was general concern regarding the potential for future declines in soil fertility. Although farmers were for the most part unhappy with their yields, there were few concrete examples of pro-active approaches to long-term fertility maintainance. This is likely due to the nascent nature of most UCRN farms: farmers have not yet developed place specific techniques aimed at cropping systems sustainability. Trees were universally viewed as important, and were valued as fuel wood, charcoal, and for medicinal purposes. Although not of primary interest to farmers, there was a general awareness that RZ trees in some way buffer the River Njoro from water deficit during the dry season. But while farmers were concerned about continued access to tree resources, they were not necessarily interested in on-farm planting unless they are to demark property lines. Still, there remains the distinct possibility that boundary plantings could be implemented as an INRM technique, especially if multi-purpose species are chosen that double as fodder and fuel wood banks, or as a source of poles and timber for construction. Prospective interventions that use trees for erosion control and fertility maintainance (for example as contour plantings or alley crops) will have to be weighed in light of this preference. Planners should also consider the social and political significance of tree planting and land tenure issues as related to their potential negative impact on ethnic relations, especially if progress is made in the Nairobi High Court's pending legal cases regarding the UCRN.

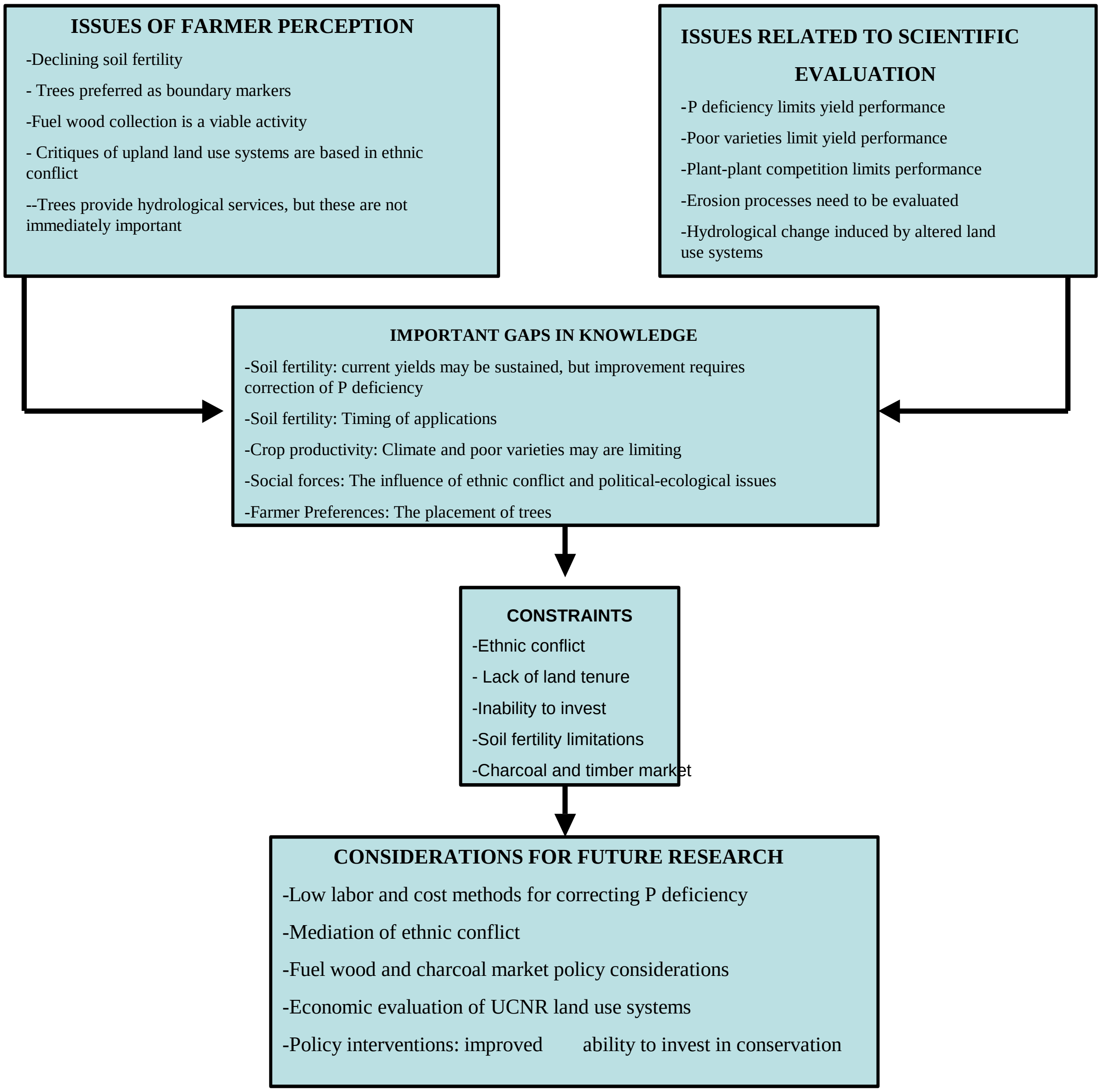

Figure 6. Conceptual diagram depicting issues of importance and future research areas in the UCRN as highlighted by this study.

Finally, there was general awareness of linkages between forests, RZ trees and continued watershed services, (as defined by rainfall capture and maintainance of stream flows), especially among Ogiek interviewees. Regardless of ethnicity, all farmers were sensitive about complaints from downstream populations regarding poor land use practices and their potential impact on the stream system in the context of existing ethnic tensions. Thus it will be important to "frame" the promotion of RZ and forest rehabilitation and conservation efforts terms of direct benefits to farmers and not as an attack on their claim to production and land rights within the watershed. In combination with a well though out strategy to minimize ethnic tension, this should be possible through direct and personalized engagement that allows farmers as a community to take charge of and participate in local planning actions.

This study's agronomic and ecological assessment of the UCRN farming system varies markedly from those reported by the farmers themselves. Specifically, P deficiency and its impact on yield performance, the use of slowly maturing cultivar varieties, the impact of climate on crop growth and the effects of plant-plant competition (in maize-bean intercrops) have emerged as scientific hypotheses explaining low yields on UCRN farms. Such hypothesizes need to be confirmed and further explored with local UCRN farmers, perhaps by scientist-farmer participatory research in the form of farmer and community trials that control for each of the above factors as an independent experimental treatment. The potential detrimental effects of erosion processes on water quality and the need for the improved understanding of human induced change on hydrological cycles remain as key concerns.

The primary gaps between farmer and scientific knowledge of the UCRN land use systems emerging from this study can be delineated as follows. Although farmers are concerned with maintaining the fertility of their soils, there is no awareness of *specific* nutrient deficiencies (for example P), nor does there appear to be an awareness of the way in which the improper timing of fertilizers and amendments could detrimentally affect nutrient uptake, nutrient use efficiency and yield potential. Also, although the placement of maize and bean seeds in each planting hole is sensible from the standpoint of labor minimization, farmers appeared to be unaware of the adverse effects of plant-plant competition for local resources and their impact on yields. Because local seed markets do not offer much in the way of cultivar variety (one brand of hybrid maize seed and one open-pollinated variety were all that was available at Njoro's farmers' stores) , farmers remain unaware of the potential to match crop varieties with specific climactic conditions.

While the agronomic, ecological and hydrological sciences are focused on biophysical processes, in the context of research in the UCRN, investigators must consistently bear in mind the pervasive influence of socio-political tensions and their influence on farmer perception and behavior. Paramount among these pressures is the impact of historical, political and ethnic tensions upon land access and tenure. Daily, these forces impact and drive farmer perceptions and practices. For example, farmer participation in forest extraction is rationalized by the need to generate additional income, because access to additional productive land is constrained by continuing immigration to the UCRN. Similarly, farmer preferences for the placement of trees is strongly influenced by the desire to demark property lines because land tenure is insecure.

In sum, the potential for future improved natural resource management in the UCRN is constrained by five primary factors: ethnic tension, the lack of secure land and farm tenure, limitations to improved crop production, the stated inability of farmers to invest in conservation measures on their acres either due to financial or labor constraints, and the continued profitability of and poverty-driven necessity of forest extraction activities. The identification of these issues highlights several areas of importance for future investigation.

Firstly, methods that are minimal in both cost and labor requirements must be developed to correct for P deficiency in UCRN cropping systems. Secondly, planners at SUMAWA-CRSP should develop strategies to minimize the influence of ethnic tension in the study area. An attempt is currently being made to do this through the use of Participatory Rural Appraisals (PRA) in several sub locations in the UCRN. This is a positive first step, although to successfully implement long-term conservation in the area, it may be necessary to develop conflict mediation strategies to support cooperation between UCRN ethnicities. Thirdly, comparative economic evaluations and modeling of UCRN land use systems (for example annual cropping, forest extraction, and livestock systems) should be conducted to comparatively judge their economic performance. Detailed analyses of these LUS can help to pinpoint specific areas where technical and/or policy interventions can have the most positive effect.

In contrast to the conventional "environmental orthodoxy" that degraded African environments result from household fuel wood shortages that are compensated for by tree felling (Leach and Mearns, 1996), it should be noted that the majority of fuel collected in the UCRN appears to be intended for sale in Nakuru, Kenya's third largest and quickly growing city. Evidence from this research suggests that activities related to the collection and transport of fuel wood constitute a viable source of additional income generation for male family members, especially during the wet season when fuel demand is heightened. In the future, these trends may shift as a result of changes in fuel wood market structures. Thus, it does not appear to be a rural fuel wood crisis that is encouraging tree felling activities in the UCRN. Instead, it maybe the complex of poor market returns for agricultural products and heightened demand for fuel by growing urban populations that drive rural actors to engage in extractive forest activities. Because increased agricultural productivity and profitability rarely succeed when used as the sole means to encourage reduced forest extraction (especially where the trade in wood products remains lucrative) planners should develop policy interventions that over time limit the profitability of this activity (Reardon and Vosti, 1995). It is important to note, however, that these interventions must be planned in such a manner as to minimize any potential adverse economic and social impacts on farmers involved in this trade. To this end, changes in the forest product market structure in these locations should only be made once alternative sources of income generation are developed, tested for viability, and successfully extended to UCRN populations.

By framing this research in a context of whole watershed health, this paper described the ways in which Njoro River upper catchment farmers view complex agroecological processes regarding soils and forest use at a variety of scales ranging from their own acres to riparian zones and the lower watershed. Consideration of bio-physical characteristics of these upland agroecosystems in tandem with farmer rationality, perceptions, and resource management methods provides valuable insight for environmental managers concerned with the implementation of improved farm and land use systems in the highlands of East Africa, and points to directions for closing the scientist-farmer gap and converging on mutually-meaningful solutions.

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