LUCID's Land Use Change Analysis as an Approach
for Investigating Biodiversity Loss and Land Degradation Project

Implications of Crop-Livestock Integration on Changes in Human Welfare and Environment
A Case Study from a Kerio River Basin Community

LUCID Working Paper Series Number 52

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December 2006

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Implications of Crop-Livestock Integration on Changes in Human Welfare and Environment: A Case Study from a Kerio River Basin Community

The Land Use Change, Impacts and Dynamics Project

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Cite working paper as follows: Author. Year. Title. Land Use Change Impacts and Dynamics (LUCID) Project Working Paper No. 52. Nairobi, Kenya: International Livestock Research Institute.

Working papers are available on www.lucideastafrica.org or by emailing lucid@cgiar.org.

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ACKNOWLEDGEMENT

This research was made possible through my fellowship program, sponsored by the Japan Foundation and the International House of Japan, as well as the recipient institution, the International Livestock Research Institute (ILRI). I would like to express special thanks to all the Rokocho people, for their cooperated as well as my enumerators, Mathew Kiprono and Rueben Kiprono during the study. Paul Kariuki helped us facilitate pre-survey. I also greatly appreciate Joseph Kimeli and Sally Kimeli, Pastor Walter Kimutai and all the other AIC (African Inland Church) staff for their warm welcome and company during my field research. I thank Patti Kristjanson, Joseph Maitima and Patrick Kariuki of ILRI who gave invaluable advice while Ianetta Mutie assisted with the data entry.

1. INTRODUCTION

Most rural households in semi-arid regions of sub-Saharan Africa practice mixed crop-livestock farming (Kristjanson and Thornton 2004). Under the subsistent mode of economy with abundant land, crop-livestock farmers have survived on consuming direct produces from crops and livestock, while balancing allocation of natural resources for producing them. In areas where infrastructural development and the introduction of education have transformed livelihoods from a subsistent mode to one more involved in monetary economy, need to earn cash has tremendously increased from both crop-livestock and off-farm activities, as lifestyle changes. Such development is often accompanied by increase in scarcity of land for extensive grazing, as population increases and more land is allocated exclusively for profitable crop production. This process of rapid intensification does not take into account the social and environmental considerations needed to ensure long-term sustainability of these new means of production. There is need to ensure sustainable intensification[1] and economically profitable integration of crop-livestock farming to meet welfare and environmental goals for people in such a system.

But would crop-livestock diversification patterns always evolve in economically profitable and in environmentally sustainable ways under rapidly changing socioeconomic circumstances? At meso-level studies, it has been suggested that population pressure would promote automatic technological intensification of crop-livestock systems (Bourn and Wint 1994). On the other hand, real intensification processes could take more complicated and diversified ways at micro-levels, often far from autonomous, depending on initial agroecological and socioeconomic conditions, as well as on policy, institutional and technological options available at a particular location (Williams *et al*., 1999).

One of the factors that make crop-livestock evolution pathways unpredictable is that different types of crops and animals may play distinctive functions in dynamic processes, while African farmers practicing mixed farming on their crop-livestock portfolios (Williams *et. al*.,1999). For example, subsistent, exotic and commercial varieties have different economic returns and are attached to different management incentives for intensification. Different types of varieties may, furthermore, interact in complicated ways. If successfully integrated, crops and livestock would not only contribute to higher productivity and income through mutually providing inputs (manure/crop residues) but also better environmental management. Some combinations of economically high-return crops and animals may be welfare enhancing, but if practiced extensively without integration, such combinations might be environmentally unsustainable. In such a case, some interventions to ensure both welfare and environmental goals are required.

Very few empirical studies to investigate socio-economic aspects of crop-livestock diversification patterns have been carried out. An attempt to present an intensive case study based on

[1] Agricultural intensification is defined as increased average inputs of labour, manure, draft power, crop residue, inorganic fertilizers, feeds, veterinary drugs, pesticides, or capital, to increase the value of output per unit of land.

household-level survey data collected through complete enumeration of a community in Rift Valley of Kenya which has been experiencing the following phenomena is made:
[1] perceived needs for alternative income sources due to population increase/education
[2] perceived serious environmental degradation due to overgrazing of indigenous animals
[3] introduction of new technologies (fruits, exotic, crossbreeds cattle, dairy goats)
This case study provides empirical evidences on conditions suitable for promoting sustainable crop-livestock production to meet both welfare and environmental goals.

This Working Paper addresses the following research questions:
(1) do different crop/livestock types have different levels of economic returns, intensification, and management incentives?
(2) what are the dominant crop-livestock diversification patterns from an integrated perspective?
(3) what are the implications of these crop-livestock diversification patterns on welfare (income) and environment (through better management)?
(4) what policy interventions can make crop-livestock diversification patterns profitable and sustainable?

Section 2 explains the backgrounds of the study. Section 3 describes differences in economic returns, intensification level and management incentives attached to different crop/animal types, and examines correlations between different activities. Section 4 identifies the dominant crop-livestock diversification patterns and investigates their implications on welfare and environment. Section 5 summarizes the findings and makes some suggestions for policy interventions.

2. BACKGROUND AND RESEARCH METHODS

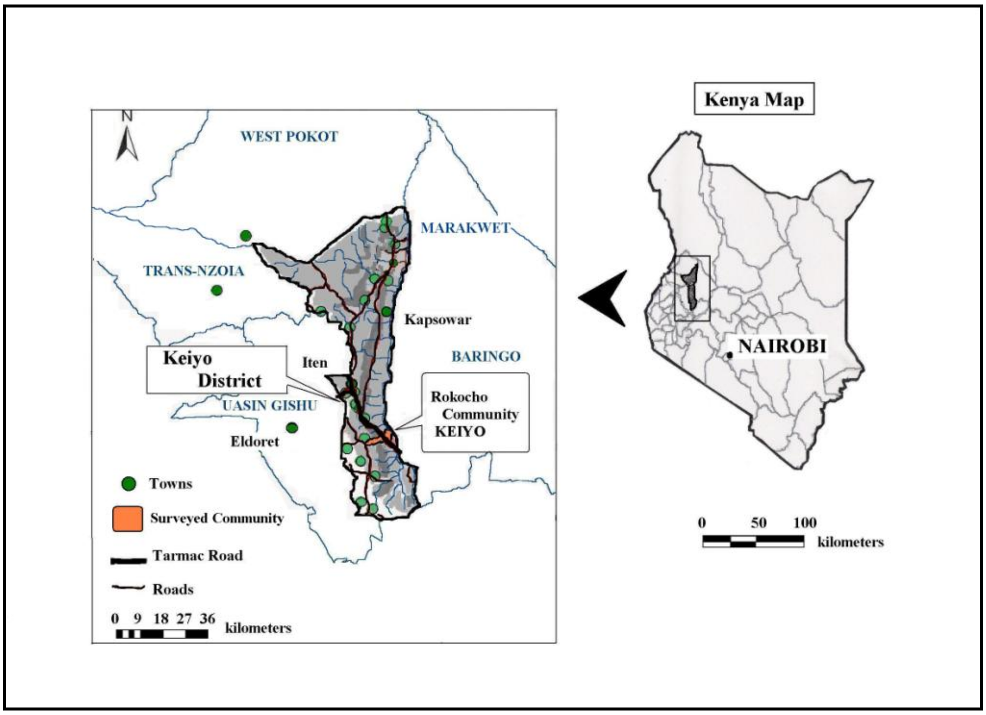
Section 2.1 defines the agroecological, socio-economic and institutional conditions of the study area. Section 2.2 describes the perceived needs for crop-livestock intensification and environmental concerns and describes drivers of development and introduction of new technologies while Section 2.3 outlines the research methods.

2.1 Rokocho Valley Community, Kerio River Basin

Physical, Agro-Ecological, and Socio-Economic Conditions

Kerio Valley is in Keiyo district along the Basin of Kerio River which flows northwards to Lake Turkana, in Rift Valley Province (see Figure 1). The valley is spanned by three agro-ecological zones. The highlands (>2,500-3,000 m) lies in the west, the escarpment (1,300-2,500 m) on the intermediate, and the lowland, or the Valley floor in the east (1,000-1,300 m) (Muchemi *et al*., 2002; Iiyama 2006; SARDEP 2002).

Map 2.1.1: Keiyo District, Rokocho Sub-Location



The Keiyo District highlands have always been exposed to market opportunities due to proximity to Eldoret in Uasin Gishu, which is part of what used to be called the "white highlands" and where Keiyo people used to seek employment on the white settlers' farms until the 1960s-1970s. In contrast, before the early 1970s, it was considered unviable to do farming in the valley due to lack of permanent sources of water and cattle rustling with neighbouring communities. People had initially settled sparsely along springs or streams (Mizutani *et al*., 2005). People slowly started to settle in the Valley floor, and especially after construction of the tarmac road in 1985. Institutions, such as churches and non-Governmental Organisations (NGOs) stimulated development initiatives, by training villagers on management skills and providing capital and infrastructure such as water tank projects.

The ILRI-JICA conducted a survey on randomly selected households from three agroecological zones between December 2004 and January 2005 in Rokocho sub-Location (Mizitani *et al*., 2005). When designing the survey for the 2006 research, the Rokocho valley community was visited again for a more intensive study.

Rokocho sub-Location is in Kibargoi Location, Soy Division, Keiyo District. It is at an altitude of 1,000-1,600 m (SARDEP, 2000b) and receives an average of 700-1000 mm of rainfall. It is warm for most part of the year with temperatures rising to between 22 and 31˚C. The Iten-Kabarnet tarmac road that traverses the sub-Location in a North-South direction is fed by several small roads. Other infrastructure such as Rokocho Primary School, the KVDA (Kerio Valley Development Agency) branch and the Cheptebo Africa Inland Church (AIC) conference centre. Most springs in the escarpment supply water for domestic and livestock use. There is need for tap water to reduce the long hours the residents have to queue to get water during dry seasons.

Institutional Setting

Land tenure system in Rokocho Valley up to the highlands is customary. Land principally belongs to each of the sub-clans. Clan land is sub-divided into extended families by the clan elders, and family land further sub-divided into parcels to nuclear families. Land in the highlands from the escarpment, to the upper part of the valley has long been sub-divided into extended families since the 1930s. while that in the lower parts of the valley started being sub-divided into families in1978, after more people started migrating from the highlands and the escarpments to settle in the Valley. Traditionally, land is owned by males who also only inherit land and other property. Land sub-division has resulted in individual family members having very small pieces of land. This has led to families determining age at which individuals may inherit land. Those that are not likely to inherit land are expected to buy land elsewhere.

Even under the customary land tenure system, individual rights to ownership of plots have been well recognized. Purchase and rental contracts of plots are common. While individual rights to land and boundaries have been well recognized, land could be used as open grazing areas for the whole clan members, it is only marked with posts or stones. Overlapping of the tenure was not a big problem when there was low population and fewer households were engaged in intensive agriculture. But as population increased, sub-divided plots became smaller and smaller. Educational needs necessitated sale of livestock and cultivation of cash crops. Fencing started in 1978 and became more obvious after the 1990s leading to reduced communal grazing. Owners of fenced plots demand high compensation for damage caused by livestock straying from neighbours plots. This has discouraged households from keeping large herds of indigenous livestock, and shift to intensive livestock management with exotic animals.

The customary land tenure system in Rokocho has not inhibited individualization /privatization of land. However, livelihood changes have led to fencing of open areas, which may lead to conflicts between intensive farming and extensive grazing.

2.2 Crop-Livestock System Integration in Rokocho

A number of families produce crops and keep livestock as a way of diversifying their income sources. It has been observed in other communities that farmers who diversify their means of production have better income than those who do not (Olson *et. al.,* 2004). This study analyzed the causes of maintaining livestock for diversification in support of livelihoods in Rokocho.

Drivers of Development

Accessibility and Institutional Support

People started to settle in the Valley after mid-1970 after cattle rusting and wild animals had been eradicated. Infrastructural and educational development in the 1980s accelerated migration to Rokocho and population growth. More development came especially after construction of the tarmac road in 1985. The trend was enhanced by construction of the AIC pipeline in 1986, construction of the community water tank by SARDEP in late 1990s and establishment of training centres by the two agencies and the World Vision.

Needs for Cash Earning Opportunities and Environmental Concerns

The pastoralist way of life depended on extensive grazing of large number of indigenous animals, supplemented by production of drought-resistant crops. The soils in the lower parts of the Valley were seriously eroded and barren due to overgrazing. But as population grew and sub-divided family land became small, it became necessary to shift grazing land to grow crops. Infrastructural and educational developments gradually transformed the lifestyle of the inhabitants, and substantially increased cash demand to meet educational needs. It became increasingly necessary for the households to adopt alternative farm activities to yield higher economic values from smaller land both for crops and livestock, without environmental costs.

Introduction of New Crop-Livestock Technologies

Development agencies tried to introduce fruits to meet both welfare (to augment income) and environmental (to promote tree planting) goals. Exotic animals are recommended and introduced by development institutions because they have higher production per animal, requiring less area for grazing, thus reducing over-grazing. Fruits were introduced by AIC and initially adopted by few farmers in Kamelgoi after 1986. SARDEP and AIC trained farmers in horticulture production after 1996. Dairy goats were introduced by AIC after 2000.

2.3 Research Methods

A questionnaire designed to capture variables in aspects of livelihoods diversification by households was administered on all the 177 households in the three villages that make the Rokocho Valley community (high-return or subsistent crop and livestock activities, as well as aspects of intensification). For livestock, information was collected on number, types, gross income, cost of animals, how they were acquired and where they are grazed (Iiyama 2006).

3. CROP AND LIVESTOCK ACTIVITIES

Section 3.1 shows livelihoods portfolios of the surveyed households while Sections 3.2 and 3.3 describe differences in economic returns, intensification levels, and management incentives per crop/ livestock type. Section 3.4 examines correlations between areas planted with certain types of crops and ownership of particular type of livestock.

3.1 Overall Livelihoods Portfolios

The main activities as sources of income in Rokocho sub-Location are off-farm, crop production, and livestock farming. An attempt is made to arrange households from higher total gross income and categorize them into the income quintile groups (Table 3.1.1). Within Rokocho sub-location, income levels are substantially different between households in Rokocho sub-Location. Higher income groups derive substantially higher income from all of the off-farm, crop and livestock activities. Contributions of each activity to the total gross income are not significantly different between the groups, except crop income. Off-farm income accounts for 47-59%, crop income for 11-33% and livestock for 15-25% on average.

Table 3.1.1: Crop and Livestock Incomes in Relative to Total Income

	quintile 1	quintile 2	quintile 3	quintile 4	quintile 5	Total	F-value
Number of households	35	35	36	35	36	177	
total income							
mean	13,544	29,537	49,497	84,548	239,365	83,989	29.26 ***
standard deviation	5,183	4,682	5,379	20,460	105,554	95,235	
total off-farm income							
mean	8,288	18,655	23,283	42,509	122,569	43,398	38.67 ***
standard deviation	6,628	10,087	15,708	25,741	108,465	65,397	
total crop income							
mean	1,471	6,565	15,001	19,994	72,194	23,324	15.98 ***
standard deviation	3,674	8,273	10,110	22,708	54,433	37,251	
total livestock income							
mean	3,485	4,248	11,462	21,576	43,268	16,927	125.71 ***
standard deviation	5,360	6,604	11,888	20,355	48,632	28,508	
ratio off-farm							
mean	0.59	0.64	0.47	0.51	0.49	0.54	1.83
standard deviation	0.39	0.34	0.30	0.28	0.28	0.32	
ratio crop income							
mean	0.11	0.21	0.31	0.23	0.33	0.24	4.33 ***
standard deviation	0.26	0.27	0.22	0.24	0.25	0.26	
ratio livestock income							
mean	0.25	0.15	0.23	0.26	0.18	0.21	1.27
standard deviation	0.34	0.24	0.23	0.25	0.17	0.25	

***.significant at<.01

3.2 Crop Production Activities

Crop Types

In Kerio River Basin, households plant various kinds of crops categorized as follows:

(a) Drought-resistant crops such as indigenous varieties such as sorghum, millet, and cassava.
(b) Staple crops such as maize, beans, cowpeas, green grams, groundnuts.
(c) Fruits such as mangoes, pawpaws, citrus, bananas, avocadoes.
(d) Commercial crops such as wheat, potatoes, carrots, mostly grown on plots in highlands.

Economic Returns, Intensification Level, and Management Incentives per Crop Type

Economic returns and intensification levels by crop types are compared. In processing the data, it turned out difficult to compare yields in weights between each crop variety, because the units of measurement are different between grain (kg) and fruits. Yields were estimated in Kenya shillings by multiplying the number of measurement unit with unit price of a particular crop to standardize the unit for comparison. Where different types of crops were inter-cropped on same plots, it was difficult to accurately calculate the amount of inputs (manure, fertilizer, labour) allocated for each crop type. In such a cases, the households were asked what percentage of the plot is devoted to a particular crop type and the quantity of manure and fertilizer inputs were estimated according to the proportions. It was not possible to differentiate labour inputs allocated to each crop in the same plots.

Table 3.2.1: Acres, Yields, Revenues, Self-Consumption Ratio, and Inputs per Crop Type

	Drought-resistant Crop		Staple Crop		Fruits		Commercial crop	
	Mean	S.D.	Mean	S.D.	Mean	S.D	Mean	S.D.
no. households (ratio)	31	0.18	101	0.57	90	0.51	9	0.05
acres	0.99	0.55	2.30	3.09	1.67	1.44	1.56	1.01
yield in ksh	5,796	4,869	27,546	34,116	21,874	33,456	39,089	32,250
yield in ksh per acre	9,050	10,177	13,484	10,687	27,342	126,443	28,828	28,023
revenue in ksh	1,127	2,135	18,918	28,698	20,416	33,440	37,167	32,934
revenue in ksh per acre	1,732	3,795	7,879	7,893	26,239	126,526	27,183	27,868
self-consumption ratio	0.80	0.31	0.46	0.33	0.11	0.18	0.10	0.16
manure (kg)	13.23	68.19	6.44	35.42	760.73	1,554.61	58.89	165.71
manure per acre(kg/acre)	10.11	38.07	5.54	29.05	462.23	874.74	58.89	165.71
fertilizer (in ksh)	0.00	0.00	8.91	89.55	0.00	0.00	2,488.89	3,040.33

Among the 177 households in Rokocho sub-Location, 18% plant drought-resistant crops, 57% staple food crops, fruits 51%, and only 5% plant commercial crop mainly on registered plots that some households inherited in the clan land in the highlands. On average, staple food crops uses most of the land (2.30 acres) followed by fruits (1.67 acres), commercial crops (1.56 acres) and drought-resistant crops (0.99 acre). In terms of yield in Kenya shillings, commercial crops yields the highest income followed by staple food crops, fruits, and drought-resistant crops. While commercial crop also earns the highest income per acre, fruits earn more per acre (KES 27,342) than staple food crops (KES 13,484). Most (20%) of the drought-resistant crops and 46% of staple food crops are consumed at home while only 10-11% of fruits and commercial crops are consumed by self. Fruits and commercial crops earn higher revenue (cross income) in Kenya shillings per acre than drought-resistant and staple food crops.

Very few households in Kerio River Basin use either organic manure or inorganic fertilizer on crops, while those planting commercial crops, mainly on plots in the highlands, apply some chemical fertilizer. On average, fruits receive more manure (761 kg, or 462 kg/acre) than the other crop types, though this amount might be too low. Some studies suggest that an annual application of 5-6 t/ha (3-3.6/acres) of manure resulted in higher yields of maize in Kenya (cited in Bationo *et al*., 2004), but staple food crops receives little (5.5 kg/acre) manure in the study area. Most plots with staple food crops are far away from homesteads in the lower parts of the River Basin. When we asked why manure application on staple food crops is so low, local people said that they believe the soil is still fertile enough while others said that another reason may be that their plots are too far away from homesteads and too large to apply manure.

Different crop types are associated with different economic returns, levels of intensification and different management activities. Drought-resistant crops are mainly planted for subsistent purpose while staple food crops generates income and food security. While staple food crops have high economic return in yield (KES), they are rather planted extensively in larger areas without any inputs because of the reasons given above. In contrast, fruits and commercial crops are intended for market and planted for commercial purpose. Though little, manure is more likely to be applied to fruits, usually planted on homestead plots, from livestock owned by households.

3.3 Livestock Production Activities

Animal Types

There are two categories of livestock:

(a) Exotic animals such as exotic-crossbreed cattle, dairy goats.

(b) Traditional animals such as indigenous cattle, sheep-goats [shoats].

Economic Returns, Intensification, Management Incentives per Animal Type

In order to compare economic cost and revenue per animal unit for different types of livestock, the number of animal holdings was converted into the Total Livestock Unit (bull: 1.29 TLU, cow: 1TLU, calf: 0.7 TLU, sheep and goat: 0.11 TLU) (Table 3.3.1).

Livestock Holdings among Households, Mode of Acquisition

Exotic and crossbreed cattle kept by fewer households (21%, 3.78 TLU on average), than indigenous cattle (45%, 6.04 TLU). Dairy goats are kept by even fewer families (10%, 0.30 TLU or 2.76 animals). Most (65%) households own on average 2.52 TLU of shoats (22.93 animals) but the standard deviation suggests a skewed distribution. Exotic animals were more likely purchased by household themselves (95% for exotic and crossbreed cattle, 100 % for dairy goats). On the other hand, 30-44% of indigenous cattle and shoats are inherited.

Grazing

Exotic animals are more likely to be semi-zero grazed (51% for exotic and crossbreed cattle and 47 % for dairy goats), or zero-grazed for dairy goats (24%). In contrary, traditional animals are grazed on open, unfenced areas, mostly within own village or in neighbouring villages.

Milk Production and Revenue

Exotic and crossbreed cattle can produce as much as 2.60 L of milk while indigenous cattle can produce 0.90 L a day, less than 1.00 L per day by a dairy goat. Exotic/crossbreed cattle and dairy goats are mostly grazed near homesteads (semi-zero grazing on family farms). Some of the milk is consumed by the household while some is sold to local kiosks or to neighbours at KES 25 L. A household can earn KES 12,000 a year if it sold half (1.3 L) of milk from a cross bred cow. Indigenous cattle produces very little milk, and are rarely milked and are left far away from homesteads for extensive grazing. Dairy goats produce more milk than indigenous ones but little is sold while most is consumed at home. Shoats are not considered for milk production.

Number of Animals Sold

More traditional animals are likely to be sold (indigenous cattle 1.25, shoats 4.04 per year) than exotic animals (exotic/crossbreed cattle 0.59, dairy goats 0.71). The sold price per animal for exotic / crossbreed cattle looks rather low, probably because young calves were sold. A dairy goat can be sold at far higher price (KES 2,129) than a local shoat (KES 785).

Table 3.3.1: Acquisition, Grazing, Revenue, Costs and Income per Animal Type

	exotic & crosbreed cattle		dairy goats		indigenous cattle		sheep & goats	
	mean	S.D.	mean	S.D.	mean	S.D.	mean	S.D.
no. of households (ratio)	37	0.21	17	0.10	79	0.45	115	0.65
no. of animals	3.95	2.45	2.76	1.64	6.51	7.18	22.93	47.30
TLU	3.78	2.37	0.30	0.18	6.04	6.58	2.52	5.20
no. of adult females(for cattle/d.goats)	2.32	1.36	1.53	0.72	3.80	4.28		
probability of inheritance	0.14	0.35	0	0	0.44	0.50	0.30	0.46
probability of purchase	0.95	0.23	1.00	0	0.58	0.50	0.75	0.44
% of open grazing	0.46	0.51	0.29	0.47	0.95	0.22	0.93	0.26
% of semi-zero grazing	0.51	0.51	0.47	0.51	0.05	0.22	0.07	0.26
% of zero grazing	0.05	0.22	0.24	0.44	0	0	0	0
milk produced per adult female (little/day)	2.60	1.99	1.00	0.75	0.90	0.98		
milk revenue per adult female (ksh/year)	12,395	13,634	537	1,515	1,085	3,449		
no.of animals sold during the past 12 months	0.59	0.80	0.71	0.99	1.25	1.80	4.04	8.10
revenue from selling animals (ksh)	5,786	7,698	3,600	4,927	8,626	11,228	4,187	8,109
sold price per animal (ksh/animal)	4,495	5,637	2,129	2,642	4,199	3,743	785	683
costs for feed per TLU (ksh/year)	1,159	1,181	107	441	0	0	3	37
total costs per TLU (ksh/year)*	1,417	1,234	7,592	7,296	676	612	1,526	1,126
gross income per TLU	7,406	6,538	15,838	27,068	2,567	4,678	1,885	2,267
net income per TLU	6,037	6,111	8,246	27,098	1,904	4,533	359	2,456

*total costs include costs for dipping, spraying, medecines, deworming, and feed.

Feed and Veterinary Costs

While indigenous cattle are freely grazed on open areas, owners of exotic and crossbreed cattle supplementary feed for nutrition. Money spent per TLU on dairy goats should be overvalued (because a dairy goat is calculated as 0.11 TLU, the amount spent per animal could be a tenth of that in TLU), but even so, dairy goats require intensive inputs than the local ones.

Differences in Management Levels between Exotic and Traditional Animals

Exotic and traditional animals have different economic returns as:

(a) Exotic: more productive asset to produce cash flow from milk

(b) Traditional: saving or asset to be easily liquidated in time of needs

While exotic animals may be kept for maximizing income, indigenous livestock are kept in semi-arid rural Africa not necessarily to contribute to income flow, but for security reasons to counter risks (Ashley and Nanyeenya 2005). Households may attach different values to exotic and traditional animals, and adopt different management such as:

(a) Exotic: investment in quality….intensive semi-zero grazing, more external inputs

(b) Traditional: investment in quantity…extensive open grazing, less external inputs

Intensive management of animals also have some implications on crop intensification. Dung of extensively grazed traditional animals is difficult to be collected, therefore rarely recycled as organic manure. Manure from animals kept within own plots are easily collected and applied to crops planted on plots nearer to bomas. Understanding implications of differences in management incentives between animal types should be important in evaluating sustainability of crop-livestock livelihoods evolutions and on economic returns on welfare.

3.4 Crop-Livestock Portfolios

The previous two sub-Sections have examined the adoption and management of particular crops/ animals by households. It is likely that there may be some patterns of adopting particular combinations of crop-livestock activities, as most African agro-pastoralist diversify their crop-livestock activities. Adopting a particular crop type (subsistent/commercial) could be associated with the adoption of a particular animal type (traditional/exotic). There may be high correlations between particular crop activities and ownership of certain animal types. As such implications of crop-livestock activities on welfare and environment, not as mutually independent activities but as particular diversification patterns with distinctive economic/management incentives should be investigated.

Before investigating such patterns, correlations between particular crop/animal types are observed Crop-livestock portfolios are defined as how households allocate land to particular types of crops and which particular types of animals households own. The variables include the ratios of land devoted to particular types of crops, total land used, the ratios of particular animal types held in total TLU, and total TLU, and are standardized into the same units. Table 3.4.1 shows a correlation matrix of standardized z-scores of the variables representing crop and livestock portfolios.

The ratio of land with drought-resistant crop is negatively correlated with land with staple food crops (-0.185) and fruits (-0.308). This shows that households devoting proportionally larger parts of land to drought-resistant crops are less likely to practise intensive horticulture and staple food crops cultivation. The ratio of land with staple food crops is highly negatively correlated with fruits (-0.589) positive with total land used (0.254), percent of indigenous cattle in total TLU (0.197), and total TLU (0.250). The ratio of land with fruits is positively correlated with percent of exotic and crossbreed cattle in total TLU (0.237). In comparison, households engaged more in fruits tend to keep improved breeds of livestock intensively, while those devoting more land to staple food crops tend to use more land extensively and to own more indigenous livestock. The ratio of exotic and crossbreed cattle in total TLU are negatively correlated with those of indigenous cattle (-0.324) and sheep/goats (-0.235). The ratio of indigenous cattle in total TLU is negatively correlated with that of sheep/goats (-0.442), but positively with total TLU (0.322). The ratios of land with commercial crop and of dairy goats in total TLU do not have any correlation with the other variables.

Table 3.4.1: Correlation Matrix

Z scores	drought-resistant	staple crop	fruits	commercial	total land used	exotic / crossbreed cattle	dairy goats	indigenous cattle	sheep/goats	total livestock
Land Allocation										
drought-resistant crop(%)	1									
staple crop(%)	**-.185(*)**	1								
fruits(%)	**-.308(**)**	**-.589(**)**	1							
commercial crop(%)	-0.086	-0.097	-0.028	1						
total land used (acres)	-0.100	**.254(**)**	0.000	0.089	1					
Animal Portfolio										
exotic and crossbreed cattle(%)	-0.133	-0.075	**.237(**)**	0.112	**.236(**)**	1				
dairy goats(%)	-0.043	0.066	-0.005	-0.024	-0.015	-0.044	1			
indigenous cattle(%)	-0.079	**.197(**)**	-0.100	-0.057	-0.053	**-.324(**)**	-0.083	1		
sheep & goats(%)	0.003	-0.120	-0.013	-0.040	-0.027	**-.235(**)**	-0.061	**-.442(**)**	1	
total livestock (TLU)	-0.143	**.250(**)**	-0.146	-0.078	0.119	0.005	-0.072	**.322(**)**	-0.040	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The finding on correlations suggests that, rather than independently dealing with variables representing engagement in each crop/livestock type, it is better to look at them in an integrated manner, by creating a new set of variables without losing information contained in the original variables. Furthermore, for later regression analyses on welfare and environment, we should have fewer and simpler variables which are uncorrelated one another.

4. CROP-LIVESTOCK DIVERSIFICATION PATTERNS AND THEIR IMPLICATIONS

Section 4 looks at crop-livestock diversification patterns and their implications on welfare and environment from an integrated perspective.

4.1 Research Questions and Hypotheses

We define "crop-livestock diversification (CLD)" patterns as particular combinations of certain crops and animal types adopted by households. As seen in Section 3, different crops/livestock types have different economic returns and levels of intensification, as well as management activities. If combined, some crop-livestock activities may be of simple diversification or of more integrated systems. According to van Keulen and Schiere (2004), "diversification occurs where components such as crops and animals co-exist rather independently on-farm. Their combination reduces risks, but their interactions are minimal. Nutrient flows are rather linear, (this form of mixing does not involve recycling of resources to a significant degree). Integration occurs where the components of the farm are interdependent, (where animals providing dung while consuming crop residues) (van Keulen and Schiere 2004, also citing Savadogo 2000).

The economic profitability and sustainable environmental integration of CLD patterns are analysed and leads to the following questions:
(1) What are dominant CLD patterns?
(2) What are the level of integration and intensification?
(3) What are the implications of particular CLD patterns on income levels or welfare?
(4) What are the implications of particular CLD patterns on the environment?

Capital asset endowments of households, (human [labour, education] and financial capital [land, labour]), and access to off-farm income would substantially affect the decisions by households to choose profitable livelihood strategies (Freeman and Ellis, 2005) as well as to undertake resource-conservation measures (Reardon and Vosti 1995; Barrett *et al*., 2002, Tittonell *et al*., 2005). Along with capital asset variables and access to off-farm income. It is assumed that different CDL patterns could have different implications on welfare and the environment through different economic returns and management activities attached to particular crop/livestock types. For example, staple food crops have high economic returns, but households have few incentives to intensify and integrate them with animal production, applying only little manure. In contrast, horticulture is profitable and owners are more likely to apply animal manure to fruits intensively, potentially leading to better environmental consequences. The hypothesis here is that different CLD patterns would affect income levels and resource management, along with variables representing capital asset endowments of households (labour, education, etc.), and access to off-farm income.

4.2 Crop-Livestock Diversification Patterns

In order to extract a new set of variables representing crop-livestock diversification patterns from the independent crop-livestock portfolio variables, principal components analysis was employed. Principal component analysis is a multivariate analytical tool used to describe the variation of a set of multivariate data in a set of uncorrelated variables, each of which is a particular linear combination of the original variables. The object of the analysis is to see whether the first few components account for most of the variation in the original data. If so, they can be used to summarize the data with little loss of information. A reduction in dimensionality is also desirable in simplifying later analyses (Everitt and Dunn 2001).

Because the variables representing crop-livestock portfolios have different units (%, acres, TLU), they were converted into standardized z scores (Table 3.4.1). Two criteria: (1) retain just enough components to explain some specified, large percentage (between 70-90%) of the total variation of the original variables, (2) exclude those principal components whose values are less than the average or 1 for this case, as the components are extracted from the correlation matrix (Everitt and Dunn 2001) were used when choosing the number of components. An attempt is made to interpret each principal component from factor weights over 0.5 in absolute values, or less if deemed necessary.

Table 4.2.1 summarizes the result of principal components analysis. Five principal components were extracted from the original crop-livestock portfolio variables, and explain 71.19% of the total variations of the data. Each of the five principal components are interpreted as follows:-.

[1] Component I: More Staple Crop, Less Fruits, More Indigenous Cattle

This component accounts for 19.96% of the total variance for the original variables. The variables, percent of staple food crops and percent of indigenous cattle, have high positive weights (0.775, 0.643), while percent of area with fruits has a negative weight (-0.663). This suggests that households with a higher score for this component may be more specialized in extensive staple food crop production and in extensive grazing of indigenous cattle, but not engaged in fruits production.

[2] Component II: Less Drought-resistant Crop, More Exotic Animals, More Fruits

This component accounts for 15.83% of the total variance for the original variables. The ratio of exotic and crossbreed cattle in total TLU (0.676) and total land used (0.534) are highly positive, while percent of area with drought-resistant crops (-0.601) is negative. Although it is less than 0.5, percent of area with fruits is 0.388, higher than those for the other components. Households with a higher score for this component may be more specialized in intensive management of improved cattle breeds, integrating with fruits production.

[3]Component III: Less Indigenous Cattle, More Land, More Shoats

This component accounts for 13.52% of the total variance for the original variables. The ratio of indigenous cattle in TLU is negative (-0.643), while total land used is positive (0.491). The ratio of shoats in TLU is 0.477, while the ratio of area with fruit is negative (-0.450). This implies that households with a higher score for this component may diversify their livelihoods into more cultivation and into grazing of sheep/goats, but not necessarily in integrated ways, while not owning indigenous cattle.

[4]Principal Component IV: Less Shoats, More Drought-resistant Crop

This component accounts for 11.24% of the total variance for the original variables. The ratio of sheep / goats in total TLU and total TLU are negative (-0.615, -0.390). The ratio of drought-resistant crop is positive (0.542) while that of area with commercial crop is moderately positive (0.361). Higher scores for this component suggest that households have few sheep and goats and are engaged more in drought-resistant crop cultivation.

[5]Principal Component V: More Dairy Goats

This component accounts for 10.64% of the total variance for the original variables. The ratio of dairy goats in total TLU is highly positive (0.915). Households with a higher score for this component are more likely to adopt dairy goats.

Table 4.2.1: Crop-Livestock Diversification Patterns: Principal Component Analysis

	Component				
	I	**II**	**III**	**IV**	**V**
	staple crop less fruits indigenous cattls	exotic/crossbreed cattle, fruits, more land	staple crop less cattle more shoats	drought-resistant crop, less shoats	dairy goats
Z-scores					
% area with drought-resistant crop	-0.028	**-0.601**	0.082	**0.542**	-0.264
% area with staple crop	**0.775**	0.124	**0.420**	-0.030	0.157
% area with fruits	**-0.663**	**0.388**	**-0.450**	-0.271	0.080
% area with commercial crop	-0.145	0.249	0.151	**0.361**	-0.216
total land used (acres)	0.151	**0.534**	**0.491**	0.003	-0.113
% of exotic, crossbreed cattle	-0.326	**0.676**	0.213	0.271	-0.095
% of dairy goats	-0.003	-0.019	0.103	0.144	**0.915**
% of indigenous cattle	**0.643**	0.075	**-0.643**	0.030	-0.061
% of sheep and goats	-0.312	**-0.424**	**0.477**	**-0.615**	-0.103
total livestock unit (TLU)	**0.543**	0.258	-0.076	-0.390	-0.205
Total	2.00	1.58	1.35	1.12	1.06
% of Variance	19.96	15.83	13.52	11.24	10.64
Cumulative %	19.96	35.80	49.31	60.55	71.19

4.3 Implications on Welfare

The determinants of total gross income, total gross crop income, and total gross livestock income are estimated here. Total gross income includes total off-farm income (regular, casual, remittance), total gross crop income (for drought-resistant, staple food crops, fruits and commercial crops, revenue (KES), not excluding labour and inputs costs), and total gross livestock income (for traditional and exotic animals, revenue (KES) from milk and from selling animals, not excluding labour and medical/ veterinary costs). The independent variables representing household characteristics to indicate capital asset endowments [such as labour, knowledge] (age, gender dummy, education year of the head, participation years in farmers group, minute distance to a local training center [AIC], and Adult Equivalent [family labour]), off-farm income dummies (regular, casual, remittance), along with the factor scores for the five principal components are included. Because the five principal component scores are uncorrelated, they can be included without worrying about multi-co linearity, which might happen if the variables representing crop-livestock portfolios independently were included.

The results are shown in Table 4.3.1. The selected independent variables explain the variances in the total gross income (53%), total gross crop income (36%), and total gross livestock income (46%). Among the household variables, age and education years are significantly positive with total gross income and livestock income. This suggests that more experienced and educated people get higher total and livestock incomes. Years in participating in activities of a farmers group is positive for total gross crop income and total gross livestock income. It probably means that exposure to knowledge through participating in activities of a farmers' group is more likely to contribute to earning higher livestock incomes. Moved dummy is positive on total gross livestock income. The effect of having stayed outside the areas (mostly in the highlands or the neighbouring districts) is less straightforward to interpret. One possible explanation is that those owning many animals but having stayed in areas where land was getting scarce decided to move to settle in the Kerio River Basin in search for grazing areas. Labour by adults resulted to positive total gross income, suggesting more labour ability contributes to intensive engagement in agricultural activity by households.

Among the off-farm income dummies, regular off-farm and casual income dummies positively affect the total gross income and total gross crop income levels. Off-farm income accounts for 50% of the total gross income and higher income casual and crop income are more important for lower income groups (Iiyama, 2006), because they do not keep enough livestock. Remittance dummy is positive on total gross crop income but negative on total gross livestock income though at 10% significance level, which is difficult to interpret at this stage of the analyses.

Among the principal component score variables, component I (more staple crop and indigenous cattle, less fruits) is significantly positive for total gross income and total gross livestock income, but not on total gross crop income. Component II (more exotic cattle, less shoats, more fruits) score is significantly positive at 1% for all the total gross income, total gross crop income, and total gross livestock income. Component II contributes to livestock income through exotic animals and crop income, probably through better integration, in comparison to component I with staple food crops and indigenous animals.

Table 4.3.1: Determinants of Incomes: OLS Estimation

	total gross income			total gross crop ncome			total livestock gross income		
	B	t-value		B	t-value		B	t-value	
Independent Variables									
(Constant)	-52883.179	-1.508		-6519.274	-0.410		-15801.951	-1.405	
age	1023.888	2.474	**	11.235	0.060		420.350	3.168	***
gender dummy (male1,female0)	-370.487	-0.026		1704.002	0.264		-6210.000	-1.361	
education years	4635.327	2.497	**	324.929	0.382		1350.779	2.270	**
years in farmer's groups	1108.127	1.001		866.491	1.722	*	909.449	2.562	**
moved dummy	12405.331	1.065		3988.855	0.748		7709.163	2.064	**
minutes distance to a training center	-277.086	-1.158		-128.445	-1.185		110.712	1.444	
Adult Equivalent	3682.611	1.191		2521.898	1.797	*	438.398	0.442	
regular off-farm income dummy	107017.534	5.077	***	19037.110	1.973	*	10238.992	1.515	
casual off-farm income dummy	33415.452	1.802	**	19162.384	2.281	**	-1538.476	-0.259	
remittance dummy	6507.366	0.280		20775.206	1.975	*	-14616.171	-1.964	*
principal component I factor score *(more staple crop, less fruits)*	8661.524	1.671	*	2996.527	1.272		665.136	5.215	***
principal component II factor score *(more exotic cattle, more fruits)*	25091.544	4.198	***	13583.450	5.017	***	8930.087	4.661	***
principal component III factor score *(less indigenous -more shoats, more land used)*	21222.371	4.075	***	12054.179	5.109	***	3772.183	2.260	**
principal component IV factor score *(less shoats, less TLU, drought-resistant crop)*	-3497.858	-0.691		1541.605	0.672		-5530.651	-3.408	***
principal component V factor score *(more dairy goats)*	-13568.913	-2.639	***	-6578.047	-2.824	***	-3598.835	-2.184	**
R Square	0.57			0.42			0.50		
Adjusted R Square	0.53			0.36			0.46		
F-value (ANOVA)	14.02 ***			7.69 ***			10.86 ***		

***siginificant at p.<.01, **significant at p.<.05, *significant at p.<.1

Component III (less indigenous cattle, but more land used with more sheep and goats) is positive for crop and livestock income. Component IV (less shoats and less TLU) is significantly negative on total gross livestock income. It is likely that they own fewer animals. Component V (dairy goats) is significantly negative for all the total gross income, total gross crop income, and total gross livestock income. This may be because goats are more likely to be adapted by low income groups rather than their decreasing low incomes.

Overall, along with household / homestead specific variables and with off-farm income dummies, crop-livestock diversification patterns seem to significantly affect income levels or welfare status of households. Principal Components II and III significantly increase total crop and livestock income levels, while Component I increases total and livestock income.

4.4 Implications on Environment

As indicated in Section 2, fencing and manure application are indirect indicators of crop-livestock intensification in Kerio River Basin. Fenced plots are mainly used for intensive farming and rarely for extensive grazing. The use of manure in live fences has made the Valley greener, increased the number of trees and improves soil fertility (Iiyama 2006). However, it is virtually impossible to measure changes in greenness at the household levels because the study area is too small to be applied by high-resolution GIS data (NDVI).

Environmental implications of certain crop-livestock diversification were evaluated by assessing their associations with fencing and manure use (ex. Clay *et al*., 2002; Tarawali *et al*., 2002). The two types of fences (barbed wire and live-fence [planting thorn trees and bushes]), and application of manure are used as indirect indicators.

Of the 177 households in Rokocho 44% have more than one plot fenced with barbed wire while 18% have more than one plot fenced with live-fences. Manure from own animals or from neighbours was used by 46% of the households. A logistic regressions analysis was carried out on fencing and manure (ex. Freeman and Coe, 2002; Place *et al*., 2002; Stall *et al*., .2002). The independent variables (household/homestead characteristic variables, off-farm income dummies, and principal component factor scores) are the same as previous analyses of OLS estimations on determinants of incomes. The estimates are correct in predicting measures by 78.5% for barbed wire fencing, 81.35% for live fencing and 84.7% for manure use.

For barbed wire, age, education years of the household head, and Components II (exotic animals and fruits) and IV (less sheep and goats) are significantly positive, while casual off-farm dummy and Component I (staple food crops, indigenous cattle, less fruits) are negative. This suggests that households with old and educated household heads owning few indigenous animals and engaged in fruit and exotic animal production more are likely to fence their plots with barbed wires than those engaged in staple food crops with indigenous cattle.

Table 4.4.1: Determinants of Undertaking Fencing and Manure

	Barbed Wire Fence		Live Fence		Manure	
	B	Exp(B)	B	Exp(B)	B	Exp(B)
households adopting	78		32		81	
	0.44		0.18		0.46	
age	0.046	1.047 **	-0.034	0.967	0.009	1.009
gender dummy (male1,female0)	0.209	1.233	1.472	4.358 *	0.008	1.008
education years	0.235	1.264 ***	-0.094	0.910	0.069	1.072
years in farmer's groups	0.049	1.051	-0.004	0.996	0.021	1.022
moved dummy	0.419	1.520	-0.849	0.428	0.420	1.522
minutes distance to a training center	-0.021	0.979	-0.014	0.987	0.000	1.000
Adult Equivalent	0.022	1.022	0.062	1.064	0.393	1.481 ***
regular off-farm income dummy	-0.737	0.479	-0.378	0.686	1.857	6.402 *
casual off-farm income dummy	-2.143	0.117 ***	0.297	1.345	1.634	5.125
remittance dummy	-0.717	0.488	0.688	1.989	1.472	4.357
principal component I factor score	-0.853	0.426 ***	-0.012	0.988	-1.035	0.355 ***
(more staple crop, less fruits)						
principal component II factor score	0.738	2.092 **	0.140	1.151	1.779	5.925 ***
(more exotic cattle, more fruits)						
principal component III factor score	-0.067	0.935	-0.555	0.574 **	-0.360	0.698
(less indigenous -more shoats, more land used)						
principal component IV factor score	0.279	1.321 **	0.334	1.397	-0.239	0.788
(less shoats, less TLU, drought-resistant crop)						
principal component V factor score	0.123	1.131	-0.177	0.838	0.050	1.051
(more dairy goats)						
Constant	-2.366	0.094	-0.575	0.563	-4.147	0.016 **
Model Summary						
-2 Log likelihood	151.055		142.793		133.804	
Cox & Snell R Square	0.40		0.13		0.46	
Nagelkerke R Square	0.54		0.21		0.62	
Prediction						
correct 0	83.84		97.24		86.46	
correct 1	71.79		9.38		82.72	
overall prediction	78.53		81.36		84.75	

***siginificant at p.<.01, **significant at p.<.05, *significant at p.<.1

For live-fence, gender dummy is significantly positive, while Component III (less indigenous cattle, more shoats, more land) is negative. This implies that male-headed households are more likely to fence their plots with thorn trees than those with less indigenous cattle but with more sheep and goats. While households with a higher score for Component III own some exotic and crossbreed cattle than indigenous cattle, they have little desire to fence their plots, probably because of being engaged in staple food crops production, but rarely in horticulture

For manure, Adult Equivalent, regular off-farm income dummy, and Component II (more exotic animals, more fruits) are significantly positive, while Component I (more staple crop and indigenous cattle) is negative. Households with a higher score for Component II that tend to plant fruits on their homestead plots with live-fence, and keep exotic and crossbreed cattle that are more likely to be managed with zero/semi-zero grazing in enclosed homestead plots. Therefore, it is easier for households to collect and apply manure on fruits from within the homesteads. In contrast, households with a higher score for Component I rarely use manure on staple food crops, despite owning many indigenous cattle. Indigenous cattle are more likely to be extensively grazed on open areas, therefore their manure is difficult to collect.

In summary, Component II are associated with better resource management through better crop-livestock integration which could have favourable environmental implications. However, while components I and III enhance diversification into staple food crops with indigenous animals, they do not seem to integrate their crop-livestock activities to improve the environment, at least by their low use of manure and fencing. Both components I and III devote more land to staple crops and less to fruits. Fruits cannot independently contribute to income without animals. On the other hand, the combination of exotic animals with staple crops may be economically a high-return pathway, but has little incentives for households to integrate them which might ultimately lead to better environment management.

5. DISCUSSIONS AND CONCLUSIONS

After reviewing the crop-livestock activities separately and independent activities, an integrated perspective was used to evaluate implications of crop-livestock diversification patterns or intensification/integration pathways on welfare and environment. It gave us better insights on crop-livestock evolution processes in the study area.

First, fruits are often associated with intensive management of more exotic animals and more manure use. This combination has an inherent management incentive for mutual intensification. Fruits are more likely to be planted on fenced homestead plots. Exotic animals are semi zero-grazed within own plots because they have high economic values, therefore their dung is easily available for applying to fruits. This combination of exotic animals and horticulture can be interpreted as an integrative crop-livestock intensification pathway, It improves the welfare of the community and is environmentally sustainable. Yet, so far, the quantity of manure application to fruits is too low while few inorganic fertilizers are used. For example, animal manure production by zero-grazed cattle in Kenya is 1-1.5 t per animal (Strobel, 1987 cited in Bationo *et al*., 2004). Use of manure should be encouraged for sustainable horticulture.

Second, the pathways of staple food crops with indigenous cattle or shoats have high economic returns, but do have few incentives to integrate their activities for potentially good environmental impacts. Many households say they do not apply manure because the plots are often far away from the homesteads. Traditional animals are extensively grazed on open areas because they have low outputs, including little manure. Because staple food crops is both a source of income and for food security, it is not recommend to shift to horticulture, before assessing profitability of horticulture against that of food crops. Therefore, it is essential to sensitize households to integrate crop-livestock activities for better manure management.

Economic gains from fruit trees can be achieved after some years because fruit trees do not start bearing soon after planting. It may also take some time and expertise for farmers to integrate them to livestock. Introduction of improved breeds may be faced with various constraints (Conelly 1998). Dairy goat pathway is associated with lower incomes, while they have potentially better economic returns than indigenous cattle and shoats. It is possible that lower income groups can incorporate dairy goats relatively easily than exotic-crossbreed cattle. The selection of crop and livestock activities may need to be compatible with household needs on food security/income and their initial management capacity. A recommendation is to integrate crop-livestock activities through sensitization. Sustainable crop-livestock livelihoods evolution can be successful only if come with appropriate support on technology transfer and environmental education.

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