Modeling Tool to Assess Economic Consequences of Changing Farming Systems for Resource-Poor Small Farmers in the Upper Njoro River Watershed, Kenya.

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A modeling tool applying net present value economic analysis was developed to estimate long-term economic returns to labor and land for smallholder cropping systems in the upper River Njoro watershed. Production expenditures and income over a 15 year time horizon, for a typical farm household cultivating 2.5 hectares of maize-bean intercrop, pyrethrum, and potato mix were characterized based on field work. Results (2003 values) indicate annual net present value returns to land under the current system average Ksh 3,488/acre ($46/acre), and net farm income to the household averages Ksh 25,646 ($342) per year. Net returns are particularly sensitive to maize yield and price, cost of seeds, and the discount rate. The tool can be adapted to evaluate the economic consequences to farmers of adopting alternative agronomic practices and cropping systems. Estimated changes in farm income can be quantified and used to assess whether economic incentives are necessary as part of efforts to investigate improved environmental land management and development programs in the Njoro watershed. Farmer field trials, research experiments, and pricing information provide the agronomic and economic data to characterize proposed new practices such as agroforesty, riparian tree planting, set-aside, and soil conservation in the model. Such agro-economically grounded quantitative estimates of smallholder income and cash flow impacts and sensitivity from adoption of natural resource management and conservation practices provide a critical input to the process of developing locally successful environmental land and water management programs in threatened resources systems such as the Njoro watershed.

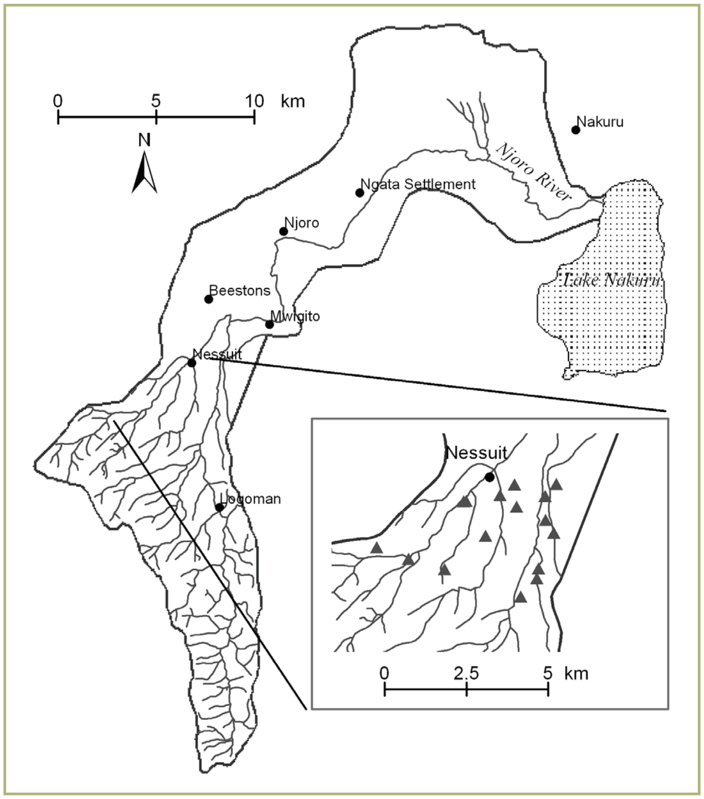
Background

The Sustainable Management of Rural Watersheds (SUMAWA) project is focused on improving watershed health and livelihood security within the River Njoro watershed. Typical of many previously forested areas of Kenya, the watershed has been progressively settled and deforested, with the latest large-scale phase triggered by the declassification of significant portions of the Mau Forest in the early 1990's. The upper catchment of the Njoro watershed has come under cultivation by in-migration of settlers to clear-cut areas. Observed changes in the river's hydrologic regime and degraded downstream water quality have alarmed researchers and stakeholders, focusing attention on relationships between upland land use and water supply.

Participatory rural appraisals and scientific investigations by stakeholders and project researchers identified agroforestry as a promising approach to counter soil and forest resource degradation as well as declining watershed services within the watershed. Adoption of agroforestry, however, represents a change from existing cultivation practices and is likely to alter the economic circumstances of watershed farmers. Tree-planting can entail significant economic risks for resource-poor farmers (Mercer 2004). SUMAWA project researchers at the University of California, Davis and Boise State University developed a simple spreadsheet modeling tool to investigate changes in long term economic returns to watershed farmers of adopting new cropping systems and practices on their land in support of broader efforts to evaluate environmental management approaches such as agroforestry.

The model applies a net present value (NPV) approach. NPV analysis computes the projected economic costs and benefits of a prescribed cropping system over multiple cropping seasons. A comparison of the NPV of alternative cropping systems as well as year-by-year costs and returns can help determine whether proposed changes would be more or less profitable and economically sustainable for farmers, compared to their current system. While NPV analysis does not account for the complex socio-cultural issues, nor all of the risks that influence small farmer behavior, it is useful in preliminary analyses of improved environmental management impacts on smallholder agriculture in the Njoro watershed.

In the NPV modeling tool, cropping system economics are modeled for 15 years beyond "year zero," the baseline when most data were collected, and to which future costs and returns are discounted. If the NPV exceeds zero, the system generates profits over the analysis horizon considered. Conversely, where NPV is less than zero, *Map of the watershed showing the locations of the 15 households of the in-depth study and general project area.*



invested funds are lost because the costs of inputs outweigh the value of returns. The modeling analysis also shows revenues and costs over time to identify any potential short term cash flow barriers to adopting new systems. Where access to credit is difficult and working capital minimal, a positive NPV may not be sufficient to encourage the adoption of a new cropping system because, despite an overall positive NPV, it is possible for producers to experience loses in individual years.

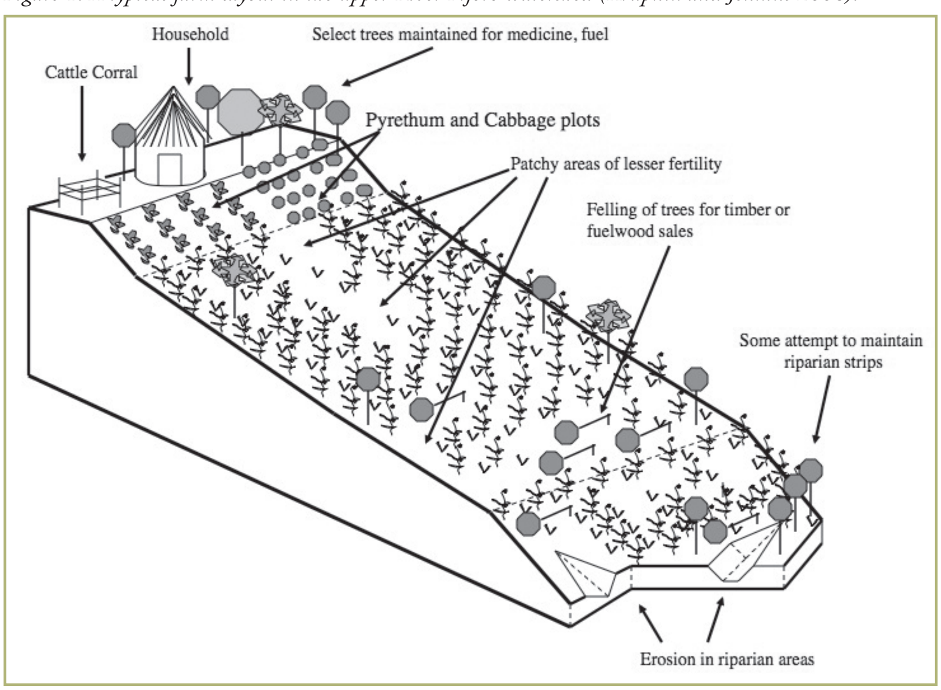
The NPV modeling tool uses multiple, interlinked Microsoft Excel spreadsheets. Generalized input and output quantities and prices are calculated for the farming system and adjusted each year to reflect annual changes in production practices. A real discount rate (inflation-adjusted cost of capital) based on actual values for Kenya of 17.08 percent per annum is applied in formulas to discount computed future year net revenue streams. Model formulas and input cells are structured, input values set, and then NPV of the characterized cropping system is computed.

Major Findings

In 2003, an in-depth study of 15 farm households was undertaken to identify predominant farming system characteristics within the upper catchment of the River Njoro watershed. Farmers described their input use and production as well as how much time they spent to complete basic agricultural tasks such as tillage, planting, weeding, harvesting, and post-harvest activities. Attention was paid to the division of tasks performed by different members of the household, especially those differentiated by gender and age, and those undertaken by hired labor. Costs and prices were recorded with information about sources, quantity, frequency and timing of other agricultural inputs and outputs.

Weighted mean data were then used to construct the archetypical crop production system of farm households in the upper catchment area. Average 2003 homestead size was approximately 2.5 hectares with another 0.1 hectares devoted to family housing and home gardens (Figure 1). Mean farm household size was six, including extended family members. Based on these characteristics, the NPV spreadsheet model was constructed assuming a cropped farm area of 2.5

Figure 1. A typical farm layout in the upper River Njoro watershed (Krupnik and Jenkins 2006).



hectares, with 75 percent planted to a maize-bean intercrop, 12.5 percent to the cash crop pyrethrum (an insecticide), and the remainder to potatoes. Although important to households' health, self-consumed home gardens and animal products have been excluded from the current NPV model formulation but could, with additional effort, be considered in future work. Krupnik and Jenkins (2006) provide a detailed description of farm and household dynamics.

*Table 1. Sensitivity to yield and price variations of NPV returns to land for the upper River Njoro watershed cropping system. kg = kilogram; ha = hectare; Ksh = 2003 Kenyan Shilling (US$1.00 = Ksh 75 in 2003). * Standard deviation of maize and bean yields derived from data reported in SUMAWA Project 2004 survey of households residing in the upper watershed.*

Maize yield kg/ha	Bean Yield Kg/ha	Maize price Ksh/kg	Annual NPV income Ksh/ ac-yr (US $)	Notes
3,113	775	12	5,978 (80)	Maize & Bean yield + 1 std dev.
3,113	452	12	5,016 (67)	Maize yield + 1 std dev.*
2,086	775	12	4,450 (59)	Bean yield + 1 std dev.*
2,086	452	16	4,420 (59)	+ 4 Ksh/kg in maize price
2,086	**452**	**12**	**3,488 (46)**	**Avgerage maize & bean yield, and maize price**
2,086	452	8	2,556 (34)	- 4 Ksh/kg in maize price
2,086	129	12	2,526 (33)	Bean yield - 1 std dev. *
1,059	452	12	1,960 (26)	Maize yiel - 1 std dev. *
1,059	129	12	997 (13)	Maize & Bean yield - 1 std dev.

Total net present value (2003 values) generated by the current small-holder cropping system over 15 years is Ksh 323,042 ($4,307), providing an annual average net return of Ksh 3,488 per acre ($46) and a household income (return to family labor) of Ksh 25,646 ($342) after factoring out family labor costs. This household income is similar to Kenya's 2003 gross national product (GNP) per capita of US $340 (FAO/GIEWS 2003), but supports six people. Households also engage in additional on and off farm activities, however, cropping income accounts for the greater portion of household income. NPV results suggest farming households in the upper watershed subsist well below the already low Kenyan GNP per capita. Estimated inter-annual variation in net crop income under the current system varies considerably but generates positive cash flow in every year, an important concern for poor small-holder households and those without access to credit.

Maize intercropped with bean, the dominant crop grown by watershed farmers, is of paramount importance to the economic viability of the current farming system. NPV sensitivity to varying maize yield, bean yield and maize price are examined and presented in Table 1. Reductions (within one standard deviation of observed data) in maize and bean yields and fluctuations in maize price have significant effects on farm income in the current cropping system; annual NPV returns could be as low as Ksh 997 (US $13) or as high as Ksh 5,978 ($80) per acre for some households in the project area.

Practical Implications

NPV modeling analysis of the existing upper River Njoro watershed cropping system provides a basis for comparative economic evaluations of farmer adoption of new practices like agroforestry among small-holders in the River Njoro watershed. To this end, three common trees (*Ficus thonningii, Grevillea robusta, Polyscuas fulva*) preferred by watershed farmers for their agroforestry benefits have been considered. Based on a comprehensive literature review, *G. robusta*, a medium size tree that is noted for rapid establishment in riverine and highland habitats, was selected for further agronomic and economic evaluation. The net present value (NPV) modeling tool can be adapted to examine how the addition of an agroforestry enterprise using G. robusta to produce fodder and green manure within the existing small-holder maize-bean cropping system, would affect the amount and stability of small-holder household crop incomes in the watershed. NPV modeling has yet to be conducted on agroforestry management using this species. Nonetheless, significant experimental work has been conducted assessing the agroecological potential (enhanced yield, production of secondary farm products and erosion control) and tradeoffs (increased competition for soil nutrients, water and light) associated with G. robusta-maize intercrops, hedgerows, and related systems in Kenya (Muchiri et al. 2002), to allow adapting the model to examine agroforestry variants and their cash flow and income effects within the current cropping system.

The NPV sensitivity analysis indicates small reductions in maize yields and prices have significant negative effects on already meager household crop income in the current cropping system. In this initial characterization, potential future declines in soil fertility were ignored but could be included by altering crop yield parameters over time. It may be possible that less reliance on maize, mal-adapted to the higher elevations of the Njoro watershed, and greater crop diversification including agroforestry, wheat, and vegetables, could stabilize household incomes, especially under potential declining yields.

Beyond agroforestry, applications for the model include evaluation of the farm income and cash flow impacts of adopting various proposed soil conservation practices and of efforts to restore riparian buffer zones on watershed farmers' lands adjacent to the stream network. For the later, the model provides an estimate of the magnitude and duration of economic incentives to compensate farmers who restore riparian zones on their lands. Such agro-economically grounded quantitative estimates of small holder income and cash flow impacts and sensitivity from adoption of natural resource management and conservation practices provide a critical input to the process of developing locally successful environmental land and water management programs in threatened resources systems such as the Njoro watershed.

Further Reading

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The GL-CRSP Sustainable Management of Rural Watersheds (SUMAWA) project was established in 2003 and is a multidisciplinary research effort focusing on biophysical and human-related factors governing health in the River Njoro watershed in Kenya. The Principal Investigator is Dr. Patterson Semenye. Email: semenye@sumawa.or.ke. Dr. Jenkins is the project's US Co-PI. Email: mwjenkins@ucdavis.edu.

The Global Livestock CRSP is comprised of multidisciplinary, collaborative projects focused on human nutrition, economic growth, environment and policy related to animal agriculture and linked by a global theme of risk in a changing environment. The program is active in East and West Africa, Central Asia and Latin America.

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