Watershed Management to Counter Farming Systems Decline

Toward a Demand-Driven, Systems-Oriented Research Agenda[1]

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Abstract

Most formal research in support of agricultural development has focused on the alleviation of farm-level productivity constraints, with problem diagnosis often occurring through a single disciplinary lens. There is a strong push within national and international arenas to move toward broader units of analysis and intervention, including the landscape, catchment and watershed. However, there is a current imbalance in the strong momentum behind this shift and the paucity of methodological guidelines for operationalizing these new approaches within research and development (R&D) circles. This paper outlines an approach for grounding watershed management in local incentives for improved natural resource management (NRM) beyond the farm level, addressing component-specific contributions to landscape degradation, and bringing formal research contributions to bear on a demand-driven NRM agenda. Following a description of a methodology used to diagnose problems at landscape or watershed level, a case study from the highlands of central Ethiopia is presented to illustrate the application of the approach within agroforestry. The case study provides a concrete example of how to move from participatory problem diagnosis to a modified research and development agenda at the landscape level.

Research Findings

- *Problem diagnosis for watershed research and development requires an understanding of both the different types of landscape-level NRM problems and how these are prioritized by different actors at the local level.*
- *An integrated research agenda at watershed level must begin with an understanding of the linkages between components (crops, water, livestock, trees, soil) and user groups, and consider the contributions that can be made by specific disciplines to the system at large.*
- *An integrated, demand-driven natural resource management agenda requires that agricultural researchers move beyond the conventional emphasis on agricultural productivity to consider how crop, livestock and tree production interact with broad-based livelihood concerns (i.e. water resources, fuel needs, income).*

Policy Implications

- *To operationalize the proposed approach, policy support is needed to expand the mandate of agricultural research organizations from disciplinary to interdisciplinary research agendas, from a focus on technology generation to "system regeneration," and to incorporate new disciplinary perspectives (social science, systems ecology).*
- *Considerable financial backing for the social sciences is also required to enhance institutional capacity to manage the social and political dynamics inherent in landscape or watershed-level interventions.*
- *Institutional policies for R&D must encourage a shift of focus from the direction of desired change to the magnitude of change required to reverse system decline, and to the capacity of the system to absorb these changes under existing conditions. Doing so will strengthen the policy contributions of research by highlighting was is and is not possible to achieve through local-level action alone.*

Keywords: African highlands, Agroforestry, Demand-driven, Farming systems, Natural resource management, Research for development, Watershed

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Introduction

Most agronomic research in support of development has emphasized farm-level productivity constraints, and diagnosed problems through a single disciplinary lens. Due in part to the limitations of this approach for managing interactions among components and actors beyond the level of the farm, a number of new approaches have emerged to address new dimensions of NRM research and practice. These include participatory watershed management (PWM), integrated NRM and collective action in NRM, among others. While diverging on particular aspects, common aims may be found:

- To enhance technological innovation by taking into account how linkages among landscape-level components (forest, water, soil) and neighboring farms influence the criteria and incentives for technology adoption (Knox et al., 2002);
- To enhance livelihood through improved management of the natural resource base supporting agriculture (De and Singh, 1999; Eren, 1977; CGIAR, 2002); and
- To enhance the benefits of 'ecosystem services' of upper catchments to downstream and urban residents, and manage flows to optimize use among multiple users (CGIAR, 2002).

These new approaches have gained significant momentum, contributing to a rather uncritical assessment of their conceptual and methodological underpinnings. Failure to fully operationalize the integrated watershed management approach, or the contributions of particular disciplines to a broad systems agenda at landscape/watershed level, has weakened the potential impact of these approaches in practice. As with earlier catchwords that accompany shifts in academic research and donor priorities, researchers and practitioners alike scramble to justify projects in terms of popularized 'selling points' – often foregoing the important step of operationalizing both meaning and motive. A question recently posed to one of the authors helps to summarize the important conceptual work that remains to be done on PWM: 'Why would a farmer *want* to think beyond the farm level?'

This paper illustrates recent experiences in PWM within the African Highlands Initiative (AHI), an ecoregional programme of the Consultative Group on International Agricultural Research (CGIAR) and the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA). Rather than focus on the conceptual and methodological foundations of PWM, which are treated in more detail in German et al., 2004, the current paper discusses an approach for operationalizing formal research contributions to PWM and for giving a 'local face' to the watershed management research agenda. Specifically, it outlines an approach for grounding watershed research in local incentives for improved NRM at farm and landscape levels, assessing and quantifying component-specific contributions to landscape and farming system decline, and bringing formal research contributions to bear on a demand-driven watershed management agenda.

Following an introduction of methods used to identify local incentives for improved natural resource management at landscape or watershed level and ensure the representation of diverse views, the paper presents a methodology for transforming identified problems into a demand-driven, systems-oriented research agenda. This is done in two steps. First, a methodology for reaching a common understanding of the linkages among system components at landscape level is described. This is followed by a case study which illustrates how interventions within a single discipline (agroforestry) can address a system-wide problem (system nutrient decline). It also demonstrates how research can generate an understanding of the degree to which local-level actions alone (in isolation from broader policy interventions) can counter negative trends in rural livelihoods and natural resource degradation. The paper concludes with a discussion of key implications of the methodology.

IDENTIFYING LOCAL INCENTIVES FOR IMPROVED NRM

For watershed management to be truly participatory, it is critical that problems and priorities at this new level of analysis be defined by local actors themselves. However, this becomes extremely challenging when moving beyond farm-level diagnosis, due to the diversity of 'local' perspectives and the integrated and social nature of causes and solutions at broader levels (Johnson et al., 2001; Meinzen-Dick et al., 2002). For such an approach to be possible, it is critical that the tools for participatory problem diagnosis enable local identification of constraints at multiple levels (farm, 'neighborhoods', landscapes). They must also ensure the participation of a broad range of social groups whose priorities, capabilities and incentives for cooperation are likely to differ.

METHODS TO IDENTIFY LOCAL INCENTIVES FOR IMPROVED NRM AT WATERSHED SCALE

It is by now widely recognized that the generation of viable land use alternatives must involve participatory diagnosis of problems or constraints (Chambers, 1994a). Without identifying issues of concern to local farmers, incentives are likely to be insufficient for actual land use change. The tendency within participatory problem diagnosis in agriculture has been to emphasize farm-level productivity constraints (Adeferis et al., 2000). While findings from such approaches are likely to illustrate major livelihood constraints, they are also likely to be incomplete. New types of questions are needed to target "watershed" or "landscape" dimensions of NRM, including trans-boundary interactions and common property resource management (German, 2003; Meinzen-Dick et al., 2002). While an open-ended exploration of livelihood constraints has its merits, it is important to recognize that the way questions are framed will influence the answers given, and that diverse methods (ethnographic, spatial, participatory) have their own respective strengths and weaknesses (Russell and Harshbarger, 2003). To generate a robust understanding of the problems underlying farming systems decline, it is therefore important that the questions posed to farmers clearly target diverse dimensions of NRM (both farm and landscape; individual and collective).

Experiences within AHI provide several lessons for how to generate such a list. First, since the concept of a 'watershed problem' is not clearly defined, interviews should include diverse questions to ensure that diverse types of problems are captured. At the minimum, questions should address the following:

- Livelihood impacts stemming from land use or landscape change;
- Problems concerning common property resource management;
- Negative impacts of practices on one farm or village on neighboring farms/villages;
- Sources of NRM conflicts; and
- NRM problems that are best addressed through collective over individual action (German et al., 2004).

Second, methods should be triangulated so that problem diagnosis benefits from the unique contribution of diverse methods. This may include a combination of individual interviews, focus group discussions and village- or watershed-level PRA's on the one hand, and ethnographic and spatial analyses on the other.

DEFINING 'THE COMMUNITY'

For several decades now, the thrust of R&D work has been directed at the 'community' or 'local level' in terms of who defines R&D priorities, who guides the implementation process, and whose reality matters (Chambers, 1994b; Cornwall et al., 1994). Development workers and researchers alike now emphasise the 'local community' when justifying and operationalising their endeavours. This emphasis has increasingly come under scrutiny due to the uncritical assumption that communities are homogenous entities for which 'one size fits all' and that one farmer's innovations will be easily shared with others (Agrawal and Gibson, 1999; Leach et al., 1999; Mosse, 1994). In fact, the literature shows that farmers have divergent resource endowments influencing their ability to innovate and different priorities influencing their desire to innovate in different domains. They also have varying levels of political clout, influencing their ability to gain access to resources (institutions, information, natural resources) (Burns et al., 1985; Fortmann and Bruce, 1988). Furthermore, one farmer's innovations are not automatically shared with others, unless they share important social ties with one another or if sharing is likely to be accompanied by certain benefits (economic, political or other) (Adamo, 2001; Armonia, 1996).

In watershed management, these differences may manifest themselves in a number of ways. People's incentives to invest in improved management of any given resource will differ as a function of their primary domains of activity, major livelihood constraints, and confidence in future access to benefits (Meinzen-Dick et al., 2002; Ostrom, 1990; Rocheleau and Edmunds, 1997). The first of these is most clearly seen in resources involved in gendered domains of activity, in which the importance of firewood and watering points to women is a clear reflection of their traditional roles. The second may be manifested by any social group, but is most apparent among users whose lesser status (social, economic, political) influences access to basic resources (Guijt and Shah, 1998; Place and Swallow, 2002). The last of these influences becomes particularly problematic when an unequally accessed resource has an important influence on livelihood and is influenced by land management patterns throughout the watershed (i.e. irrigation water), as the distribution of costs and benefits of improved management is unequal (German, 2004; McDonald, 1991). The importance given to different issues is also likely to vary by age and/or time of residence in the area, important determinants of environmental knowledge (Zent, 2001; 1993) and awareness of problems that manifest themselves over longer time periods. These influences are illustrated in the results of a socially-disaggregated participatory ranking activity carried out by site teams in two AHI benchmark sites, in which farmers were asked to rank locally-identified watershed issues on the basis of their perceived importance. Individual ranks were averaged across individuals representing different social categories: gender, wealth, age and landscape position. Selected findings are presented in Table 1.

Table 1. Key Watershed Issues Ranked by Social Category at Two AHI Benchmark Sites [a]

Watershed issue	Ranks by Social Category [b]	Explanation
A. Lushoto benchmark site, Tanzania (total of 40 issues)		
1. Limited availability of potable water	Men:Women = 15:2 Upslope:Downslope = 1:15	Women are responsible for fetching water; water is more abundant in valleys
2. Insufficient irrigation water in the dry season	Men:Women = 8:18 High:Low Income = 21:10	Cash cropping tends to be a male domain; high income stems from & fosters access to water resources
3. Insufficient respect for farm boundaries	Men:Women = 13:27	Men own farmland
4. Need for group tree nurseries	Men:Women = 13:2	Prioritized for firewood; potential source of income irrespective of landholdings
5. Individual tenure of water resources	Men:Women = 16:6	Women suffer the consequences of individual ownership of water sources (harassment, conflict)
B. Ginchi benchmark site, Ethiopia (total of 28 issues)		
6. Deforestation	Men:Women = 11:2	Women gather fuel wood and suffer labor consequences of its diminishing supply
7. Shortage of grazing land	High:Low Income = 2:15	Wealthy farmers own more cattle
8.Impact of eucalyptus on crops & soil	Elder:Youth = 8:26	Elders more easily observe environmental impact of exotic species from extended observation over time
9. High cost of fertilizer	Elder:Youth = 15:2	Youth are more interested in modern farming practices and must use small landholdings intensively

[a] Adapted from AHI-Ginchi (2003) and AHI-Lushoto (2003).
[b] Ranks refer to the priority given to each watershed issue relative to others, wherein a "1" refers to the issue of topmost priority. In Ethiopia, the number of watershed issues identified and ranked was 40 (averaged across 2 villages), while in Tanzania the total number of issues ranked was 28 (1 village).

The relative influence of different social variables (for example, gender) on expressed priorities within local communities will differ across societies. Variables of universal relevance are likely to include gender and wealth, due to the tendency across all societies for domains of activity to be gender-specific, resources to be distributed unequally and development interventions to perpetuate existing gender and wealth inequities (Lastarria-Cornhiel, 1997; Rocheleau and Edmunds, 1997; Schroeder, 1993). The influence of age can also be considered universal due to its influence on people's ability to observe long-term change. Additional site-specific variables should also be identified and incorporated into the design of watershed processes. For example, landscape position (where a family resides or cultivates) may have an important influence on livelihood constraints and access to resources (see example 1, Table 1). Yet the specific characteristics of landscapes, settlement patterns, landholding distribution, and farming systems are likely to influence how such categories are defined. Where a family's landholdings are confined to the upper or lower portion of the landscape, for example, ranks of residents living in upper and lower parts of the landscape may be contrasted. In cases where landholdings are more randomly distributed on the landscape or where all farmers own similar strips of land, such spatial variables may be more easily analyzed with respect to specific landscape features (i.e. proximity of household to watering points). Munk Ravnborg and Ashby (1996) illustrate the fundamental importance of moving beyond pre-defined social categories to include more constructivist approaches to stakeholder identification and consultation.

ASSESSING THE INTEGRATED FOUNDATIONS OF FARMING SYSTEMS DECLINE

Interdisciplinary brainstorm on linkages between components and users

Once the priorities of different local stakeholders are identified, it is important to develop a strategy for R&D interventions. This is not a straightforward task, as the selection of priority interventions could rest on any number of factors, including:

- Resources of critical importance to livelihood (i.e. water), even if prioritized by few social groups;
- Issues prioritized highly by most watershed residents or groups;
- Availability of feasible solutions and relevant expertise; or
- Components or interventions with the greatest potential to catalyze system-wide change.

Within AHI, two approaches have been used. In the first, site teams looked at how priorities play out across social categories and tentatively ranked as 'high priority' those issues that rank high by a large portion of the population (as illustrated by average and socially-disaggregated ranks). These findings were fed back to the community to verify the importance and prevalence of each issue. The issues were then scrutinized by researchers to identify a few issues or components that could be addressed simultaneously so as to enable important biophysical synergies to emerge. In the second approach, the complete list of issues emerging from the field was scrutinized by an interdisciplinary team of scientists prior to community feedback to identify important opportunities for interventions with system-wide repercussions. While the effects of each approach have yet to be seen, a combination of approaches is likely to be most effective.

An important method underlying either approach is an 'interdisciplinary brainstorm', which enables component researchers to envision otherwise familiar NRM issues in terms of their landscape-level dimensions. Within AHI, this activity has been carried out through a social learning approach. Multidisciplinary site teams composed primarily of biophysical scientists from diverse fields (soil, livestock and crop science, agroforestry) and regional research team members (selected on the basis of complementary expertise in social science, systems agronomy, systems ecology) plan and implement jointly. Consensus-based decision-making is used to ensure a common understanding of the problems and the way forward prior to implementation.

This interdisciplinary brainstorm approach was used to collectively interpret the 'watershed issues' identified by farmers, and consider possible interventions. One of the most critical junctures in this discussion occurred when interpreting locally identified problems in terms of their 'plot' vs. 'watershed' dimensions. Initially, while many researchers saw the emerging problems as no different from those identified during prior participatory rural appraisals of plot- and farm-level problems, other researchers trained in social and systems approaches were able to identify clear differences. This discrepancy led the site team at Holetta Agricultural Research Centre (HARC), Ethiopia, to suggest a clarification of what exactly gives a biophysical problem a 'watershed' dimension, leading to the formulation of indicators of watershed-level processes. Three indicators were proposed by the team as jointly defining a 'watershed problem': (a) it is widespread (affecting many families), (b) it benefits more from collective than individual action, and (c) it calls for multiple solutions and the integration of components.

Since the meeting at Holetta, some further refinements to these indicators have been made (German et al., 2004). First, 'integration of components' has assumed a slightly different meaning at farm and landscape scales. While trees, crops, livestock and soil are present at both levels, there are additional components absent from farm-level analyses yet central to landscape/watershed-level analyses including water (springs, streams, irrigation canals) and other common property resources (communal forests or grazing areas). Furthermore, while component integration at farm level addresses the interaction of components within a single farm, integration at landscape/watershed level must address component interactions between farms and between farms and other landscape units (forests, springs, etc.). Differences in how 'the same' problem is conceived of at plot/farm and landscape/watershed level are illustrated in Table 2, and derived from a series of social learning events at site level in all three countries in which R&D strategies for watershed management were jointly developed and field-tested[2]. In this table, the implications of moving from farm- to landscape-level analysis are apparent – namely, the inherently collective and interrelated nature of problems at this new level of analysis[3]. Appreciation of these differences is growing among HARC scientists. The biggest barrier to more widespread acceptance is perhaps the paradigmatic shift represented by a move from component-level objectives (i.e. maximizing the productivity of a single farm-level component) to higher-order, systems-related objectives (i.e. getting research within different disciplines to contribute to the system at large and to components that emerge at landscape level).

Only once a collective understanding of the interrelated nature of problems at watershed level is reached should potential solutions be considered, as the formulation of research objectives and questions is very much influenced by how problems are perceived. An example from the resulting work plan of the HARC site team helps to illustrate this difference for the agroforestry component:

Plot-Level Research Objective (hypothetical)

Objective 1. To increase the productivity of timber and other tree resources on farm.

Watershed-Level Research Objectives (actual)

Objective 1. To increase the prevalence of trees in their appropriate niches to minimise runoff and enhance spring recharge while increasing the availability of tree resources (fodder, fuel, cash, timber);

Objective 2. To identify opportunities for arresting system nutrient decline through the integration of trees into the landscape, and the identification of fuel options that do not degrade the surrounding landscape (forest, soil, water).

Inherent in the watershed-level objectives is the need to consider component interactions at landscape level, as well as the social implications of diverse interventions (i.e. the need to negotiate appropriate solutions for different landscape niches). The case study presented below illustrates how a demand-driven, systems-oriented research agenda may be formulated. It focuses on the second of these two watershed-level objectives: assessing the potential of the system to produce a sustainable fuel supply without contributing to system nutrient decline.

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[2] While some variation exists between countries, research priorities in National Agricultural Research Systems (NARS) of eastern Africa are similar due to their common foundations in western scientific establishments. The observations in Table 2 are derived from ongoing debates on how research mandates of NARS change when moving from plot/farm to landscape/watershed scale.
[3] While this analysis emerged in part from the discussion at Holetta, it also summarizes attitudes prevalent within National Agricultural Research Systems in the eastern African region at large.

Table 2. Differences between Plot- and Watershed-Level Analyses of Identified NRM Issues [a]

Identified Issues	**Plot-Level Analysis**	**Watershed-Level Analysis[b]**
Declining quantity & quality of drinking water (all)	Falls outside mandate	*(1)* Solutions require collective action because water is influenced, owned and used by all; *(2)* Water quality and quantity is influenced by land use (erosion, livestock management, vegetation) and influences health & labor, requiring an integrated approach to optimize diverse system goals.
Soil fertility decline & erosion (all)	Need for chemical & biological soil amendments, SWC measures and improved land husbandry	*(1)* Open access to dung during the dry season limits options for enhancing the productivity of these same plots when converted to cropland, requiring consensus for remedial actions to be effective (ET); *(2)* Nutrient flows from upper to lower part of the landscape require an integrated approach; *(3)* Nutrient resources are concentrated in homestead plots at the expense of outfields, requiring an integrated diagnosis and interventions; *(4)* Tree species & location have a direct and indirect impact on soil fertility (through nutrient cycling and soil stabilization, and their impact on fuel wood and dung use), and must be integrated into soil conservation efforts.
Impact of exotic trees on water, crops, soil (all)	Exotic species must be genetically improved to reduce impacts	*(1)* Exotic species may be currently integrated into landscape niches that are system-incompatible or socially-detrimental; it is important to consider the impact of different species (indigenous, exotic, clonal) on the environment (water, soil), productivity and neighboring farms to identify more appropriate niches; *(2)* Mechanisms for equitable stakeholder negotiation at diverse scales are required to optimize the benefits & minimize the costs of tree cultivation practices for different stakeholders.
Land shortage from population pressure (all)	Falls outside mandate	*(1)* Entire system is in decline due to population pressure, which is both cause (of deforestation, water resource degradation, shortened fallow/productivity decline) and consequence (of limited economic opportunities – esp. for women, child mortality, low access to or acceptance of family planning), requiring an integrated approach to income generation and NRM.
Shortage of livestock feed / grazing land (ET)	System is too extensive and livestock breeds unproductive	*(1)* The problem is widespread; solutions require collective action due to communal grazing practices; *(2)* Strong causal relationships exist between soil fertility, crop and fodder productivity, fallow duration and fuel (dung & crop residues extracted as fuel/feed), requiring an integrated approach; *(3)* An opportunity may exist to transfer labor currently allocated to free grazing into system intensification.
Shortage of irrigation water (TZ, KY)	Poor water use efficiency on farm	*(1)* Net effect of individual land use practices on water discharge requires negotiation of water-compatible trees and soil and water conservation measures to enhance infiltration at catchment level; *(2)* Solutions require collective action to balance the benefits and costs of water conservation because irrigation water is influenced by all and accessed by few (TZ, KY).
Excess run-off (ET)	Insufficient SWC structures at plot level	*(1)* The biophysical interactions between landscape positions (water & nutrient flows) should be acknowledged in solutions (common drainage ditches, connectivity of conservation measures).
Wood shortage (ET)	Yield of indigenous species is low; insufficient land allocated to trees at household level	*(1)* Wood shortage is widespread, influencing landscape degradation through the effects of deforestation on soil and water, and increased use of dung for fuel; *(2)* Appropriate landscape niches are needed to integrate more trees into the system according to species-specific impacts (on soils/crops/water), system compatibility & household resources / constraints.
Loss of indigenous tree species (ET)	Falls outside mandate (except in ET)	*(1)* Favourable characteristics of indigenous species are at risk due to extirpation (localized extinction accompanying deforestation) & inability of farmers to propagate some species; *(2)* Need to seek niches for the re-integration of culturally important species where system-compatible; *(3)* Collective action for sustainable management of remnant trees and forest is an urgent need.

[a] Adapted from AHI-Ginchi (2003); AHI-Lushoto (2003); [b] Where issues are prevalent in several sites (left column), landscape analyses may differ. For interpretations that differ across sites, the sites to which that particular analysis pertains are specified in the right-hand column (ET = Ethiopia, KY = Kenya, TZ = Tanzania).

GROUND-TRUTHING SCIENTIFIC ASSUMPTIONS AND PREMISES

While the 'systems thinking' in Table 2 may seem valid, it is nevertheless critical that the interpretations of scientists be validated in the field. This validation can be done through biophysical methods and/or farmer interviews. Examples of the first include sampling of water to verify the presence of livestock-transmitted disease and quantify sediment loads, or quantification of the amount of fuel derived from different sources (dung, cultivated trees, forest). Social scientific methods may be used to validate the specific aspect of each problem that is weighing most heavily on livelihood. For example, is deforestation and loss of indigenous tree species perceived as a priority problem due to limited access to fuel wood, loss of indigenous species previously preferred for certain uses, broader impacts on soil and water, or all of these factors? Additional aspects that should be looked into with more qualitative methods are prior attempts to address each problem (to identify what solutions have already proven ineffective, and why), specific bottlenecks to their effective resolution (technical, social, policy), and the spatial and social distribution of the problem and related causal processes. Tools that may assist in this ground-truthing include semi-structured group or individual interviews, participatory mapping of problems and spatial dimensions of cause-and-effect, and participatory or scientific resource flow assessments.

FORMAL RESEARCH CONTRIBUTIONS TO A DEMAND-DRIVEN WATERSHED AGENDA

An Example from Agroforestry in the Ethiopian Highlands

Case studies serve to illustrate new principles or approaches through concrete examples. While most cases illustrate actual experiences with the application of (or failure to apply) certain principles, the following case study differs in its emphasis on planning and on the formal research component of a linked R&D agenda. It emerged out of a process of participatory problem identification at the landscape/watershed level and an interdisciplinary 'brainstorm' on the watershed dimensions of these problems. It has been formulated both as an independent PhD project (to be conducted by a HARC scientist) and as a component of the overall watershed action plan at the Ginchi benchmark site.

Benchmark sites within AHI are selected on the basis of two basic criteria: (a) the degree to which they exhibit shared characteristics such as high population density, declining agricultural productivity and advanced stages of natural resource degradation, and (b) how representative they are of a larger region. The idea behind this selection is to test approaches to widespread problems through work in pilot sites, where experiences may be compared regionally and extrapolated to a larger region. Ginchi, located in West Shewa Zone in the central highlands of Ethiopia, is one of two AHI benchmark sites in Ethiopia. The farming system is a mixed crop-livestock system characteristic of a large portion of the Ethiopian highlands, where high-value crops (garlic, potato, enset) are cultivated in homestead plots (infields) and staple crops (mostly barley) in outfield areas. Individually-owned outfields are left to open access grazing following the barley harvest. Nutrients are transferred from outfields to homestead plots both directly through dung collection, and indirectly through the 'parking' of livestock near homesteads at night. This management system, prevalent throughout much of the Ethiopian highlands, makes research-for-development particularly challenging, as it requires an appreciation of the complex linkages between tenure systems (individual, communal) and landscape components (infields, outfields) in both space and time.

As formulated, the following research protocol demonstrates an attempt to operationalize a watershed research agenda within a specific discipline (in this case, agroforestry) through the articulation of the linkages to broader social and landscape-level processes. Methodological contributions emphasize how research within a single component can contribute not only to component-specific objectives (maximizing the yield of tree products on farm) but to ameliorate system-wide trends in natural resource degradation. The approach is unique in looking beyond the *direction* of desired change (more trees of particular species in particular niches) to the *magnitude* of change required (number of trees required to reverse identified degradation processes) and the system's potential (agronomic, ecological and social) to meet these goals.

PROBLEM STATEMENT

During the initial watershed exploration at the Ginchi benchmark site (Galessa highlands), farmers expressed a general trend in natural resource degradation in which population growth, deforestation, soil fertility decline and decreased livelihood opportunities are causally connected (AHI-Ginchi, 2003). A lengthy fallow period together with manure deposits through outfield grazing once helped to maintain soil fertility. Now, a shortening of the fallow period from population pressure, increased use of dung for fuel (a result of deforestation), and additional nutrient extraction through the diversion of crop residues to the homestead (as a source of feed in the dry season) have seriously taxed the system. When dung was in short supply, local residents used to spend an entire day (out of 3) gathering fuel wood from public lands (the Chilimo Forest), but access has recently been severely restricted. On the other hand, forest depletion and soil erosion have contributed to a significant decline in the quantity and quality of water resources, leading to competition between humans and livestock and conflict between neighboring villages in the dry season. Watershed issues identified by local residents (Box 1) represent consequences of such changes.

Box 1. Major NRM issues in Galessa

- Soil fertility decline / shortened fallow
- Deforestation
- Loss of indigenous tree species
- Poor water quality
- Shortage of livestock feed
- Loss of seed/soil/fertilizer from run-off
- Land shortage
- Water shortage for livestock & humans
- Wood shortage

The first step in analyzing such findings is to understand the functional linkages between identified problems. This enables experts within specific disciplines to look into possible solutions not only from the perspective of their discipline alone, but from the perspective of broader system impacts of technological options and innovation. While this case study illustrates the role of trees and watershed-level agroforestry research in countering system decline, the approach can apply equally to other disciplines implicated in the outcomes of participatory diagnosis (soil science, hydrology, animal science).

In the Galessa highlands, there is a current effort by the non-governmental organization (NGO) Farm Africa has recently supported a forest decentralization process for the Chilimo Forest that divests management responsibilities from the central government to communities. While enhancing access to forest resources for communities adjacent to the forest, tit has severaly restricted access by watershed residents. This has made sustainable fuel wood production a critical priority. It has also placed added pressure on the system, providing added incentive to use dung for fuel and cultivate fast-growing exotic tree species whose negative effects on soil, crops and water are already apparent. To counter the fuel wood contribution to system decline, there is an urgent need to determine the potential for supplementing what is currently derived from unsustainable sources (Chilimo forest, nutrient extraction from outfields) through localised fuel wood production.

To understand the potential for increasing local fuel wood production without exacerbating system degradation, it is important not only to determine species-specific yield and impact on ecological variables, but socially and agronomically compatible niches for planting more individuals of these species. For example, eucalyptus is known by local residents in all AHI sites to exacerbate water shortages and to impact negatively on crop yield despite its multiple uses and favourable growth characteristics. Socially and agronomically compatible niches for these species may be difficult to find, but distance from communal watering points and whether nearby land uses are jeopardized should be considered in selecting appropriate niches. Rather than focus solely on biomass production at the farm level, a 'watershed' perspective is necessary to understand the biophysical influence of trees on other landscape components. These include soils (affected directly through species-specific impact on nutrient cycling, and indirectly through the relationship of firewood abundance and the burning of dung), crops and water (i.e. discharge rates). This enables a more nuanced understanding of the ramifications of farm-level technological innovation in terms of impacts on other landscape components and social groups.

Regarding potential niches for the integration of more trees in the Galessa watershed, it is important to research how the characteristics of different species influence their compatibility with different parts of the system. On communal & degraded lands, co-management and adaptability to degraded soil conditions will influence niche compatibility; in outfields, cattle browsing, soil fertility and water interactions are considerations; in valley bottoms, adaptations to seasonal water-logging are critical; whereas on farm boundaries, impacts on neighboring plots are important. The characteristics of different species also influence which species are preferred for different uses, and enable or hinder their cultivability by different types of farmers (Adeferis et al., 2000; Kindu, 2001). These characteristics will have an important influence on adoption potential and rates (Franzel and Scherr, 2002), and must be considered if realistic assessments are to be made of the potential to integrate more trees into the landscape to provide a sustainable supply of fuel.

To generate a realistic assessment of the potential for integrating more trees into existing farm and landscape niches, the above factors will need to be considered along with technical assessments of species performance. This can be done by researching the feasibility (cultural, technical, economic, ecological) of integrating more trees into existing farm and landscape niches, and comparing this potential with the magnitude of change needed to counter unsustainable practices (the difference between what is currently derived from sustainable and unsustainable sources). Results would have significant implications for energy policy through a realistic assessment of the potential (or lack thereof) for localised solutions to the fuel wood crisis. This will enable the generation of realistic recommendations on what technical and policy recommendations are needed (if any) to bridge the gap and to reverse the contributions of fuel scarcity to system deterioration.

RESEARCH OBJECTIVES

The overall objective is to identify opportunities for arresting system degradation through the integration of trees into the Galessa landscape, and the identification of fuel options that do not degrade the surrounding landscape (forest, soil, water). Specific objectives would then be to:

1. Quantify and characterize current fuel consumption in the watershed;
2. Determine the environmental impacts of current fuel use on the system;
3. Identify additional fuel wood needs to counter the effects of fuel scarcity on system decline;
4. Identify potential niches where trees can be integrated in the landscape, and system-compatible species for these niches;
5. Determine the difference between ideal cultivation scenarios (highly suitable, preferred and compatible species by groups, use and landscape niche) and actual practices (the prevalence of different species in different niches), to identify important barriers to the effective integration of preferred species into the system; and
6. Identify viable options for meeting current and projected fuel needs on a sustainable basis.

Specific objectives 1 through 3 help to quantify current fuel uses, the environmental impact and sustainability of alternative sources, and the amount of fuel required from new sources to avoid component-specific contributions to system decline (i.e. from unsustainable practices). This last step is often missing in system diagnosis, yet can be instrumental in determining whether localised land use changes are alone sufficient to reverse negative trends (in this case, in order to achieve sustainability in fuel wood production). It can be done by assessing total current fuel consumption, amounts derived from different sources (fuel wood, dung, tree products, crop residues, kerosene), and the impact of different sources (type, species) on system nutrients and water discharge. Identifying social parameters (i.e. wealth) that influence current access to alternative sources will also help to assess technical and policy options for different households.

Objectives 4 and 5 target the social, ecological and agronomic potential for integrating more trees into the landscape. These steps are innovative in combining assessments of agronomic / ecological compatibility (potential for different species to be integrated into different farming system and landscape niches) and cultural preference (cultural assessments of species traits for different uses), as well as suitability to different household-level livelihood priorities and constraints, when determining the potential for corrective change. They are also innovative in assessing actual behaviour (species currently cultivated in different niches), and using observed discrepancies between preferences and actual practices to identify current barriers to the integration of preferred species into the system. This can in turn aid in identifying critical leverage points for innovation.

Objective 6 aims to assess the potential to meet the current fuel deficit through wood biomass production under the existing farming system. This is done by contrasting the amount of fuel required from new sources (system needs, as assessed in objectives 1 through 3) with the potential for cultivating more trees of different species in diverse landscape niches (agronomic, ecological and social criteria, as assessed in objectives 4 and 5). Discrepancies between total fuel needs and the potential for increased fuel wood production help to determine whether it is possible to meet current and projected fuel needs through local sources (agroforestry), or whether external technical and policy interventions are needed.

Methodology

A proposed methodology for operationalizing specific objectives is presented in summarized form in Table 3. The quantification and characterization of current fuel consumption practices (Objective 1) is required to identify the relative contributions of fuel from sustainable and unsustainable sources. Unsustainable sources are those that are currently contributing to system decline, as defined by a net loss of nutrients from the system (soil stocks, standing biomass, etc.). Focus group discussions are used to identify different sources of fuel, and how fuel use patterns are distributed within the population (e.g. differences resulting from proximity to Chilimo Forest, household wealth, or other relevant social and biophysical parameters). This is aimed to ground-truth variables that will be used within more formalised household surveys. Surveys will then be used to verify the key determinants of suggested patterns of fuel consumption within the population. Once key patterns are identified (i.e. greater proportion of fuel source i used by household type x), actual fuel use of a representative sample of households selected according to identified use patterns and determinants will be monitored systematically through informant recall methods. Overall fuel consumption will then be determined through extrapolation of findings to the population at large.

Once current use patterns are determined, the environmental impacts of current practices can be determined to differentiate between sustainable and unsustainable practices (Objectives 2 and 3). This will be done through the quantification of nutrient flows within the system related to current fuel sources (dung, crop residues, tree products from Chilimo forest, trees on farm). This requires the assessment of overall flows (from informant recall) as well as of the nutrient content of these flows during different seasons. Overall nutrient sinks will be identified through mass balance calculations, and subsequent research activities aimed at identifying the potential of the system to reverse these nutrient sinks. In addition to nutrient flows, it is important to understand other types of interactions between diverse tree species and the system (positive and negative effects on system hydrology, allelopathic interactions, etc.), so that these can be managed when seeking alternative fuel sources.

Once the total additional fuel requirement needed to substitute the amount of fuel obtained from unsustainable sources is determined, the methodology moves on to assess the actual potential of the system to counter current deficiencies through niche-compatible afforestation. This is done by assessing the potential of different landscape niches (Objective 4) and social niches (Objective 5) to absorb or integrate more trees of different species without exacerbating current negative tree-system interactions. The potential for the integration of different species of trees within specific landscape niches is determined through local knowledge assessments (see German et al., in press) and species adaptability trials (Berhane et al., 2004). The potential to integrate different species into different households (social niches), on the other hand, will be determined through a host of social scientific methods. These aim to understand not only species preferences for different uses (species people would wish to have access to under the ‘ideal’ scenario), but also the actual ability of different households to cultivate preferred tree species (the ‘real’ situation). The latter, in turn, is assessed through research on farmers’ perceptions (interviews) and behaviour (actual cultivation practices). Data will be analysed to assess discrepancies between ideal behavior (preferred species by niche and household) and actual behavior (what species are cultivated where). Semi-structured interviews are then used to determine the barriers (technological, social, economic, policy) to converting ideal behavior into reality. This enables the identification of opportunities that may exist for more strategic interventions (technical assistance, credit, policy reform) to enable farmers to integrate more trees of more appropriate species into existing social and landscape niches.

Table 3. A methodology for Operationalizing Agroforestry Contributions to System Regeneration

Purpose	**Methodology**
***Specific Objective 1*: Quantify and characterize current fuel consumption**	
Identify local determinants of current patterns in fuel consumption (amount, type)	Focus group discussions
Characterize fuel use by different sub-sections of the population	Household surveys to identify key determinants of current patterns of fuel use (social or farming system variables) and determine % of families fitting different fuel use patterns
Quantify fuel use for a sample of the population acc. to identified determinants	Monitor fuel use (amount, source) over 2 years by families fitting identified determinants (monitor 1 week/month)
Extrapolate fuel consumption trends to entire population	Numerical extrapolation based on household surveys, actual fuel consumption patterns and known watershed demographics
***Specific Objective 2*: Determine system impacts resulting from current patterns of fuel use (dung & wood)**	
Nutrient impacts:	
Identify nutrient content of dung and crop residues used for fuel	Sample dung seasonally & analyze chemically; sample residues & analyze chemically
Quantify amount of dung and residues taken from outfields and homestead plots for fuel.	Household surveys (above)
Determine the soil nutrient contributions from leaves of different tree species (cultivated and preferred)	Litter bags; laboratory digestion experiments
Hydrological & agronomic impacts:	
Quantify effects of different tree/shrub species on crop yield and water discharge	Determine crop yield & soil water content at different distances from tree lines; measure seasonal discharge of streams; spatial analysis of land use:discharge correlations
***Specific Objective 3:* Identify additional fuel wood needs to counter effects of fuel scarcity on the system**	
Extrapolate to determine net environmental impacts of different tree species	Determine the presence and abundance of dominant species according to social characteristics & landscape units
Differentiate between sustainable and unsustainable sources (mass balance calcs.)	Classify identified fuel sources according to their environmental impact
Determine fuel requirements to substitute unsustainable sources	Standard calculations (energy, biomass)
***Specific Objective 4:* Identify potential landscape niches for afforestation and system-compatible species**	
Identify and characterize landscape niches	Participatory mapping; semi-structured interviews
Determine the likely compatibility of different spp. in different landscape niches	Semi-structured interviews to identify niche compatibility criteria; participatory ranking
Determine the performance of different species in different landscape niches	Experiments on early survival of different tree species in different landscape niches
***Specific Objective 5:* Determine incentives and barriers to effective integration of preferred species**	
Determine local preferences for different species, considering both uses and impacts	Semi-structured interviews to identified uses & impacts; preference ranking
Determine the suitability of different species by niche, in view of the livelihood priorities and constraints of different households	Semi-structured interviews with representatives of diverse social groups (as in Step 1) to identify opportunities & constraints to the cultivation of different species in different niches
Determine actual cultivation practices	Characterize species presence and abundance by niche for a sample of households (as in Step 1)
Identify discrepancies in ideal and actual tree cultivation behaviour	Contrast preferences & practices; semi-structured interviews to understand discrepancies (constraints to the integration of preferred species in different niches)
***Specific Objective 6*: Identify viable options for meeting fuel needs on a sustainable basis**	
Assess potential wood biomass production in the existing farming system	Compare yield estimates of preferred, suitable & compatible species with the potential of different niches to absorb more trees
Assess technical / policy options for meeting fuel needs from local and alternative sources	Compare potential biomass production with that needed to counter unsustainable practices

The final step of the methodology (Objective 6) utilises all the above findings. It assesses the gap between the current unmet fuel demand (the amount of fuel currently derived from unsustainable sources) and the potential for localised solutions (amount of additional fuel wood that can be realistically supplied through modifications the current farming system). Insurmountable barriers to the integration of more trees into appropriate niches or to very large deficits in current fuel use (i.e. amount derived from unsustainable practices) may be identified. In these cases, policy recommendations would recognize the need for exogenous solutions such as alternative fuel sources to complement local agroforestry solutions.

Discussion

The above methodology is innovative in moving beyond technical interventions aiming to move the system in a certain direction, to assessing the magnitude of change required to reverse current degradation processes – and the social and biophysical potential of the current system to absorb these changes. It is also innovative in moving beyond a component-specific goal (enhanced yield of tree products) to address a critical household need (fuel) and considering the system-wide ramifications of failing to supply that need (system nutrient decline). The methodology is also innovative in assessing the viability of alternative technologies (i.e. tree species). This assessment is carried out not only according to the ideal scenario (identification of those species preferred for different uses), but according to the actual ability of different social groups to integrate different tree species into their farming systems while minimizing the negative consequences of doing so. It is also worth noting how niche identification, system compatibility, cultural preferences (species preferred for different uses or avoided for their harmful impacts) and socio-economic suitability are all considered when assessing the potential for integrating more trees into the landscape and specific farming systems. Finally, assessing the social, agronomic and ecological potential for integrating more trees into the landscape yields crucial information on the relative importance of local (technical) and higher-level (policy) interventions in reversing a critical driving force behind landscape-livelihood decline in the Ethiopian highlands.
This particular case illustrates a number of general principles or lessons that may assist in formulating watershed management R&D programs, including those that differ in discipline or mandate. One important lesson derived from this case study is the need to move beyond the conventional mandate of agricultural research organizations (i.e. agricultural productivity) to consider how diverse landscape-level components and processes interact. The research mandate must also expand to include components that are not found at farm level, including water and common property resources. When a landscape view is taken, each of these dimensions becomes very much relevant to the diagnosis of livelihood constraints due to their interrelationship with other components of the landscape or farming system. By acknowledging the linkages between landscape components (water, forest cover, soil, land uses) and local actors, even component-specific research can be undertaken in such a way as to be informed by – and contribute to – broader landscape processes.

A second lesson is the need to move beyond farmer *preference* criteria for different technological options (based on their cultural value) to consider social and biophysical *compatibility* criteria. This is important at the household level, where socio-economic characteristics of the household or farming system influence what any given household is capable of. It also matters at the landscape level, where technological innovation within one component can have negative spin-offs within other components and influence technological adoption and livelihoods accordingly. While there may be a high level of agreement on farmer preferences for different species as a function of their use values, their actual ability to cultivate preferred species on farm is likely to be conditioned by their compatibility within the system and specific household goals and constraints. This being the case, both farmer motives and constraints, and their ideal and actual behavior (preferred vs. cultivated species), should be given equal consideration. The observed discrepancies between people's preferences (the ideal species for different uses) and their actual behavior (which species are actually cultivated in different social and landscape niches) may help to identify critical bottlenecks keeping people from realising more ideal scenarios. While some of these bottlenecks may prove to be intractable, others may lend themselves to simple technological, policy or organisational solutions. For example, teaching people how to propagate certain species, or encouraging multi-stakeholder negotiation at the local level on appropriate landscape niches for different species, may be sufficient to catalyze change.

A final lesson from this paper is the need to conceive of agricultural research and development in broader terms than technology generation and dissemination. The above methodology illustrates how the objectives of agricultural research can emphasize broader dimensions of livelihood than agricultural productivity per se (i.e. fuel and water availability, labor), and broader system goals such as arresting system nutrient or water degradation in addition to component-specific productivity concerns. When conceived of at the landscape or watershed level, technologies are assessed according to broad systems or social criteria (system compatibility, cultural preference, socio-economic suitability), and project aims go beyond the specific confines of components and disciplines to address integrated livelihood and systems concerns. The end goal of such watershed-level R&D efforts is therefore not to enhance the productivity of a particular commodity per se, but to enable synergistic effects among components and actors. By working toward system-wide goals within different components or disciplines, greater gains may be realized at community and landscape levels – even from work carried out within the confines of a single discipline.

Conclusions

Participatory watershed management represents an important opportunity for addressing issues in innovative ways by expanding the range of social and environmental benefits from otherwise isolated interventions. This paper illustrates one example of how research within a single discipline (agroforestry) can enhance the ecological and economic integrity of the system at large by addressing component-specific contributions to system decline, and considering the defining elements of household economies and component interactions. For such interventions to be truly responsive to local concerns, however, it is important that they be grounded in local priorities and criteria and in the effective integration of disciplinary perspectives and expertise. Ultimately, this may require institutional innovations to enable new approaches to problem diagnosis and research, such as multidisciplinary programs and planning procedures, the funding of new disciplinary emphases (social science, systems ecology), and transformed incentive structures in which relational, systems-oriented research at broader spatial scales is rewarded. This will require considerable policy support and institutional innovation in the definition of research mandates; design of multidisciplinary planning and implementation methods; and fund reallocation for more balanced support to social and biophysical, component and systems-oriented science within agricultural research organizations.

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