

Innovative Research Approaches for Mountain Regions

Operationalizing Systems Integration at Farm and Landscape Scales

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Abstract

Most research in support of agricultural development and natural resource management in densely settled mountain ecosystems continues to emphasize component over systems-level goals. Research by plant breeders, (agro)foresters and animal scientists is generally designed to maximize the yield of products within their particular areas of expertise (edible plant parts, tree products and livestock products, respectively), while soil scientists aim largely to increase soil nutrient stocks. At landscape level the same dynamic holds within the agronomic sciences, while water engineers work independently to conserve water through its isolation from broader landscape dynamics, and other common property resources remain largely ignored. Opportunities to foster positive synergies between system components, and to integrate livelihood with conservation goals, are generally missed.

This paper presents experiences of the African Highlands Initiative, an ecoregional program of the CGIAR and a network of ASARECA (the Association for Strengthening Agricultural Research in East and Central Africa), in operationalizing integrated research at farm and landscape scale. Following a discussion of the shortcomings of the conventional research paradigm, the paper lays a conceptual foundation for integrated research. System components at farm and landscape level are delineated, and this somewhat arbitrary conceptual partitioning of agroecological systems shown to influence the current research paradigm as well as the partitioning of institutional mandates. Diverse meanings of systems integration are then discussed to illustrate the synergies that might be built into agricultural and natural resource research programs. The distinction between the logic of maximization and optimization is then utilized to distinguish between component and “system-level” goals. This conceptual overview is followed up with several case studies to illustrate how these concepts can guide the formulation of integrated research objectives, methods and outputs at farm and landscape scale. The paper concludes with a discussion of the implications of this alternative research paradigm for the structure, function and skill base of national and international research systems.

Keywords: Farming systems; Integrated research

Introduction

Agricultural research continues to face criticism for its shortcomings in reversing current trends toward increased poverty and natural resource degradation. While some of these criticisms would be better attributed to broader structural constraints, shortcomings of the conventional agricultural research paradigm are nevertheless apparent. Researchers continue to frame research objectives, questions and methods with limited consultation of farmers and limited consideration of other disciplines, and to emphasize technological over other aspects of agricultural development and natural resource management. New research paradigms such as participatory research, farming systems research and extension and integrated agricultural research for development have come a long way in addressing some of these shortcomings – at least in principle. However, most of these approaches are ill-suited for working with the social and biophysical complexity of natural resource management systems. This paper seeks to operationalize the role of research in understanding interactions, and fostering positive synergies, between system components at farm and landscape scale to better support the integration of short-term livelihood with conservation goals.

Background

THE CONVENTIONAL RESEARCH PARADIGM

Inherent in the conventional agricultural research paradigm is a conceptual distinction between crops, livestock, trees and soil. This conceptual break-down structures skill development (in the form of highly specialized or disciplinary university degrees), departments within research organizations, research objectives and methodologies (which are generally discipline-specific), and planning and review processes. The structure of government line ministries also reflects this conceptual partitioning of the natural world. While Ministries of Agriculture tend to work with all of the above components simultaneously (with the frequent exception of the tree component), agricultural production is seen as distinct from environmental protection and water resource management - which are generally embedded within separate ministries of environment and water resources. Research by plant breeders, (agro)foresters and animal scientists is generally designed to maximize the yield of products within their particular areas of expertise (edible plant parts, tree products and livestock products, respectively), while soil scientists aim largely to increase soil nutrient stocks. At landscape level the same dynamic holds within the agronomic sciences, while water engineers work independently to conserve water through its isolation from broader landscape dynamics, and other common property resources remain largely ignored.

In addition to disciplinary biases which structure agricultural research, there is a bias toward plot or farm-level perspectives and the individual over the collective. These biases are apparent in the limited research on common property resources, in the emphasis on agricultural production in isolation from other aspects of livelihood (i.e. how land use influences the domestic water supply), and in the failure to consider the social consequences of farmer innovation (i.e. how land use decisions of one farmer influence neighboring farmers or downstream residents). They are also apparent in the individualized mode of decision-making fostered by research and extension. While the increased legitimacy of farmer research groups as a means to structure the researcher-farmer interface has fostered farmer-to-farmer learning, decision-making on technological innovation remains at the level of the individual.

THE NEED FOR AN ALTERNATIVE RESEARCH PARADIGM

Increasing recognition of the failure of the conventional agricultural research paradigm to catalyze widespread technology adoption and livelihood improvements has catalyzed a search for new research paradigms. While often only partially applied, participatory research is one alternative paradigm that has shown much promise for increasing impact through the integration of farmers' priorities into research. Farming systems research and extension, while not living up to its promise in terms of impact, was unique in seeking a strong integration and synergy among biophysical components at farm level. Yet research in each of these paradigms remains at a largely technological level, analysis and intervention is confined to the farm level, and decision-making remains at the level of the individual (Table 1). Integrated agricultural research for development, another emerging paradigm, seeks to integrate technological research with social, policy and institutional aspects of agricultural development. This paradigm shows promise in integrating research on non-technological processes, and linking to political and administrative units and processes at diverse levels. These new levels of intervention also bring in collective decision-making between farmers and outside actors. Yet while the integration concept is still emerging, a move beyond technological to biophysical rationales, the integration of biophysical elements and processes at farm and landscape scales, and collective decision-making among local land users are not prominent in writing or actions on the ground (Acosta et al., 2005; Bashaasha and Boesen, 2004; Rees and Nampala, 2004).

Integrated Natural Resource Management has emerged as an alternative concept for adaptive and integrated management of natural resources at diverse scales (Hagmann et al., 2002; Lal and Lim-Applegate, 2001; van Noordwijk et al., 2001). By building upon the most promising aspects of other research paradigms but the social and biophysical interactions and trade-offs that characterize resource use in densely settled agricultural landscapes more explicit, the concept has the potential to serve as an integrative framework for agricultural research and development (Table 1). However, much work remains to be done to operationalize the research

component of INRM. This paper begins to address this gap by focusing on how the “P” in INRM may be operationalized by researchers.

Table 1. Comparison of Existing and Desired Agricultural Research Paradigms

Parameter	Participatory Research	FSRE	IAR4D	INRM
Level of Participation ^a	High	High	High	High
Dimensions Addressed	Technological	Technological	Technological, Policy, Social, Institutional	<i>Biophysical</i> , Social, Policy, Institutional
Level of Intervention	Plot	Farm	Farm, District	Farm, <i>Landscape</i> , District
Level of Decision-Making	Individual	Individual	Collective (local-external)	Collective (<i>local-local</i> and local-external)
Level of Interdisciplinarity	Medium (not explicit; often demand by farmers)	High (biophysical)	High (diverse)	High (diverse; <i>biophysical integration explicit</i>)

^a Levels of participation across each paradigm are high in principle, but often less than participatory in practice.

PROGRAM CONTEXT

Research was conducted under the rubric of the African Highlands Initiative, and eco-regional research program convened by the World Agroforestry Centre on behalf of the Consultative Group for International Agricultural Research (CGIAR) and a network of the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA). The program’s core objective is to improve livelihoods in densely-settled highland areas through improved agricultural productivity and natural resource management (NRM). AHI operates through a series of benchmark sites in each of four countries, where site teams composed of national agricultural research and extension systems, local government and NGOs pilot new methods and approaches for assisting rural farmers. Methods are developed through an iterative process of planning, field-testing, reflection and re-planning at community, site and regional levels. While some methods are largely empirical, emphasizing technology evaluation or system characterization, others have an action research orientation in which the key ingredients to an effective change process are understood by implementing and observing such processes in practice. This paper summarizes observations made through close collaboration with agricultural researchers and extension personnel and their host institutions in AHI benchmark sites.

Toward an Integrated Research Paradigm

DELINEATING SYSTEM COMPONENTS

Within the agricultural research paradigm, “system components” roughly correspond to the boundaries of biophysical disciplines: crops, livestock, trees and soil. While these components capture much of the “structure” of single plots or farms, they are inadequate for capturing structures and processes at landscape level. While water is present at farm level as a resource for agricultural production, its social function (water for domestic use) only becomes visible at landscape level. It is at this level where the sum total of management practices on individual plots and farms becomes apparent in terms of the effects on the quality and quantity of water in springs and waterways. Yet the social function of water remains invisible within agricultural research and development institutions, whose institutional mandates are restricted to agricultural production. At landscape level, the bias toward private land tenure is diminished as alternative tenure regimes become ‘visible.’ Common property resources such as forests, waterways and communal grazing areas are acknowledged at this scale as tree, water and livestock components, respectively, or become system

components in their own right. These resources must find a place within the agricultural research and development paradigm due to the strong causal linkages between tenure regimes (Meinzen-Dick et al, 2002).

While such distinctions are found in scientific and traditional knowledge systems worldwide (Atran, 1990; Berlin, 1992), they are also somewhat arbitrary – partitioning the natural world into discrete components despite the nutrient, hydrological and biological processes which connect them. Despite these limitations, this conceptual break-down of the biophysical world can be useful in building more integrated, systems-level research and production systems if the relationship between components – as opposed to the individual components alone – becomes a foundation of professional practice.

THE LOGIC OF MAXIMIZATION VS. OPTIMIZATION

Implicit within the dominant scientific paradigm is a logic of maximization. Scientists within individual disciplines work to maximize returns to the particular system component that aligns with their area of expertise. Foresters seek to maximize the yield of diverse tree products, while crop scientists seek to maximize the yield of edible plant parts (seed, fruit or tuber). This logic finds its roots in highly uniform, industrialized production systems that predominate in the West, where large tracts of land are allocated to the production of a single product – be it milk, meat, timber or grain. Such a paradigm yields highly specialized crop cultivars, livestock breeds and tree species that have perfected the art of maximization, as illustrated by the dairy vs. meat cow dichotomy. While the logic of increased yield is of itself worthy, it is important to recognize the implication of transferring the scientific logic of maximization of highly uniform production systems to the integrated systems of smallholder farmers. When diverse components of the system (crop, livestock, tree, soil) are brought together within a small land area, transformations within one component of the system have direct effects on other system components and trade-offs are abundant. Mechanisms by which trade-offs are manifest include modifications of the nutrient cycle, system hydrology or population biology (within- and between-species interactions). Introduction of some high-yielding crop varieties divert nutrients from the livestock component, given the plant's reallocation of energy from leafy biomass to grain and the resulting decrease in fodder production. Introduction of some fast growing tree species can divert water from the soil and groundwater, having a negative impact on the yield of neighboring crops and on spring discharge. Finally, high-yielding crops and improved breeds are generally more susceptible to pests and disease, illustrating how the selection of certain genes over others can introduce risk for farmers through the modification of species-species interactions.

This paper argues for a new scientific paradigm for smallholder farming systems based on the principle of optimization. As opposed to maximizing yields of a single component (tree, crop, livestock or soil) or product (timber, fruit, fodder or fuel), optimization seeks to balance gains and losses to diverse system components, products and goals. Research questions would shift from, “What species yields the highest x” to look more like, “What is gained and lost to components a and b from technological innovation x?” and “What technological innovations optimize gains to components / objectives x and y?” This strategy would help to minimize risk while enhancing system productivity overall by acknowledging the ramifications and spin-offs of different management decisions and enabling more informed farmer innovation processes.

DEFINING SYSTEM INTEGRATION

Acknowledging Component Impacts on Other Components (Component Integration)

The first integration concept, outlined in some detail above, refers to the integration of system components at farm and landscape scale. Farm-level components include trees, crops, livestock and soil, while landscape components include common property resources (including the social function of water). “Integration” in this case implies moving beyond component-specific objectives (i.e. maximizing the yield of edible plant products) to broader systems goals including optimizing returns to diverse components. It implies acknowledging interactions and trade-offs, and managing them to optimize returns to diverse components while minimizing negative spin-offs of technological innovation.

Integrating the Priorities of Diverse Social Actors into Research (Constructivist Integration)

The second integration concept involves the integration of priorities of diverse social actors into research. Two forms of constructivist integration will be addressed here. The first is participatory research, in which the farmers' priorities (research objectives, treatments, variables, outputs) are integrated with those of researchers – with different forms of research definable by the degree to which each of these two social actors shapes decision-making (Biggs, 1989). Variables that will often enter into research through participatory processes (which would otherwise be absent) include those associated with risk; those explicating trade-offs related to re-allocations of limited resources (land, labor, organic nutrient resources, capital); and cultural variables associated with local culinary practices and preferences, ritual functions of natural resources or patterns of reciprocity. One hypothesis is that the more participatory the research, the more the outcomes will align with component integration since farmers are by necessity systems thinkers and tend to prioritize multiple goals simultaneously (i.e. increasing crop *and* livestock production).

The second form of constructivist integration is inherently political, acknowledging the social trade-offs of current and alternative land use scenarios by making explicit who gains and who loses from diverse technological, social or institutional innovations. This concept emerges from the political ecology literature (Rocheleau et al., 1996; Rocheleau and Edmunds, 1997; Schroeder, 1993), which has laid the groundwork for understanding how decision-making processes within local communities and the attitudes and practices of outside actors are rooted in political interests. By making social trade-offs explicit during the planning stage, alternative solutions or means of implementation can be considered that aim to optimize gains to diverse social actors. By monitoring who wins and loses during an implementation process, creative strategies can be developed to ameliorate losses suffered by given land user and to enable more equitable access to the benefits stream.

Seeking Positive Synergies among Diverse Types of Interventions (Sectoral Integration)

The final integration concept links local technological or biophysical integration to the social, policy and institutional processes required to bring far-reaching change, building upon the IAR4D concept. The sectoral integration concept helps to frame scientific inquiry on how technological interventions can be best sequenced with negotiation processes, participatory policy reforms and strategies to enhance market access so as to foster multiple goals simultaneously (i.e. income generation, equity, good governance, sustainable NRM). It also ensures research moves beyond farmer innovativeness and empowerment to understand the broader structural constraints to development and more sustainable management of natural resources.

Case Studies

COMPONENT INTEGRATION: EXAMPLES AT FARM AND LANDSCAPE LEVELS

Component Integration in Practice: Managing Spin-offs of Technological Innovation at Farm Level

Opportunities for enterprise diversification and income generation in higher altitudinal zones of the Ethiopian highlands are constrained by climatic factors. The Ginchi benchmark site, located in the Galessa highlands of West Shewa Zone, Ethiopia, is characteristic of these constraints. Efforts of the horticultural research program at Holetta Agricultural Research Centre have received much praise due to their efforts to devolve seed potato production to smallholder farmers. Use of the Farmer Field School approach has enabled farmers to master fitosanitary measures to produce clean potato seed, while in-kind loans of seed, fertilizer, agrochemicals and zinc roofing (for the construction of diffused light stores) has enabled investments that would otherwise have been impossible for resource-poor households. The successes of the program are threefold. Enabling a shift from ware to seed potato production in the area has led to sharp increases in household income among participating farmers. Secondly, small up-front investments (limited to local material and labor contributions) have enabled the most resource-poor farmers to benefit, as illustrated by the percentage of households in high, medium and low wealth categories participating in FFS (21.4, 40.0 and 25.8, respectively). Finally, the approach has partially alleviated the national deficit in seed potato supply, with benefits that reach far beyond the seed producers themselves.

As the initiative has spread, market forces have encouraged a shift in seed potato varieties and interest in measuring impact has spread. Being a nutrient-demanding crop, spread of Irish potato production is also likely to have profound impacts on system nutrient stocks and, as a consequence, on the productivity of other farm enterprises. However, research has been slow to respond to these new dynamics through a shift in research questions and variables. While market dynamics call for an assessment of seed potato varieties according to market demand, the need to track economic impact calls for a shift to net income per unit area. Yet yield and culinary properties remain the key proxies for varietal performance and impact (Woldegiorgis et al., 2004). Variables for understanding system ramifications (trade-offs and opportunity costs) of increased Irish potato production remain absent. A more integrated research process in line with the component integration concept would assess system-wide trade-offs of increasing the area allocated to Irish potato, and of different varietal-nutrient management combinations in the study area. New research questions emerging from an emphasis on component integration (column 3 of Table 2) shift our attention from yield and culinary properties alone to the impact of different scenarios (more or less land allocated to Irish potato, variety x or y, and different nutrient management practices) on yield, income, soil nutrient stocks and productivity lost to other farm enterprises. This brings an interest in the system at large, rather than a single component (in this case, a single species within the crop component), into focus – better aligning researchers with system-wide goals and sustainability concerns.

Table 2. A Comparison of Non-Integrated and Integrated Research for Seed Potato

Aspect	Non-Integrated	Integrated (spin-offs to other components managed)
Research Questions	1) Which seed potato variety performs best at Galessa? (<i>crop</i>) ^a 2) What varieties are preferred as boiled potato? (<i>culinary</i>) ^b	1) What are the trade-offs (effect on potato yield and income, soil fertility, productivity of other farm enterprises) of the shift from ware to seed potato production at Galessa? Of different seed potato varieties and nutrient management practices? (<i>crop – target and others, livestock, soil, economic</i>)
Variables	1) Yield of seed potato 2) Local ranks of different varieties when prepared (boiled)	1) Potato yield, income from potato, soil fertility, nutrient flows at farm level, nutrients exiting system (for each of the treatments – including traditional ware potato system)
Outcomes	1) Highest yielding seed potato variety at Galessa 2) Increase in farmer income from potato	1) Farmers are aware of what is gained and lost to household income, system nutrient stocks and yield of other farm enterprises from the shift from ware to seed potato production (and different varieties/nutrient management practices), and are better able to target corrective measures for managing negative spin-offs.

^a Italics denote the particular system components or dimensions researched.

^b While not integrated in terms of the component integration concept, tracking culinary properties *is* integrated in terms of inclusion of farmers' priority variables into varietal evaluations. That said, there is a tendency to generalize the variables assumed to be of interest to farmers rather than engage in more detailed consultative processes to ground truth these assumptions on a case by case basis. In this case, market demand would serve as a better assessment of consumer demand than culinary assessments within the "supply" zone.

Ex-Ante Component Integration: Integrated Planning at Landscape Level

The impact of interventions on component interactions can also be anticipated at the planning stage, and integrated into research and development efforts. Ex-ante assessments of these interactions can assist in generating system-level research goals, and identifying research and development interventions needed to achieve these. This example comes from a watershed diagnosis and planning initiative at Ginchi benchmark site. Following a series of focus group discussions by gender, wealth and landscape location to identify landscape-level natural resource management issues of concern to farmers, a participatory ranking of these issues was conducted. This resulted in prioritization of the following problems:

1. Poor water quality and quantity for humans and livestock
2. Loss of indigenous tree species
3. Loss of soil, seed and fertilizer from excess runoff
4. Low soil fertility
5. Lack of improved seed
6. Feed shortage
7. Fuel shortage

Subsequent clustering of issues with strong functional interactions led to the identification of two intervention areas with higher-level “system” objectives (Table 3). A schematic diagram of the first cluster (Figure 1) illustrates the principle of component integration at landscape scale, where water becomes a key variable and synergies among components (left-hand arrows) are sought through activities means to address multiple problems simultaneously.

Table 3. A Comparison of Non-Integrated and Integrated Research for Cluster 1

Cluster Name	Problems Addressed ^a	Research Objective
Soil and Water Conservation and Utilization	<ul style="list-style-type: none"> • Poor water quality and quantity for humans and livestock • Loss of seed, fertilizer and soil from excess run-off • Loss of indigenous tree species • (Crop failure due to drought) 	To enhance the positive synergies between water, soil and tree management in micro-catchments.
Integrated Production and Nutrient Management	<ul style="list-style-type: none"> • Feed shortage • Lack of access to improved seeds • Wood shortage / loss of indigenous tree species • Soil fertility decline • (Land shortage due to population pressure) 	To improve farmer incomes and system productivity (crops, livestock, trees) while ensuring sustainable nutrient management in the system.

^a Secondary problems (those identified by farmers by not prioritized as highly as primary problems) are denoted by parentheses.

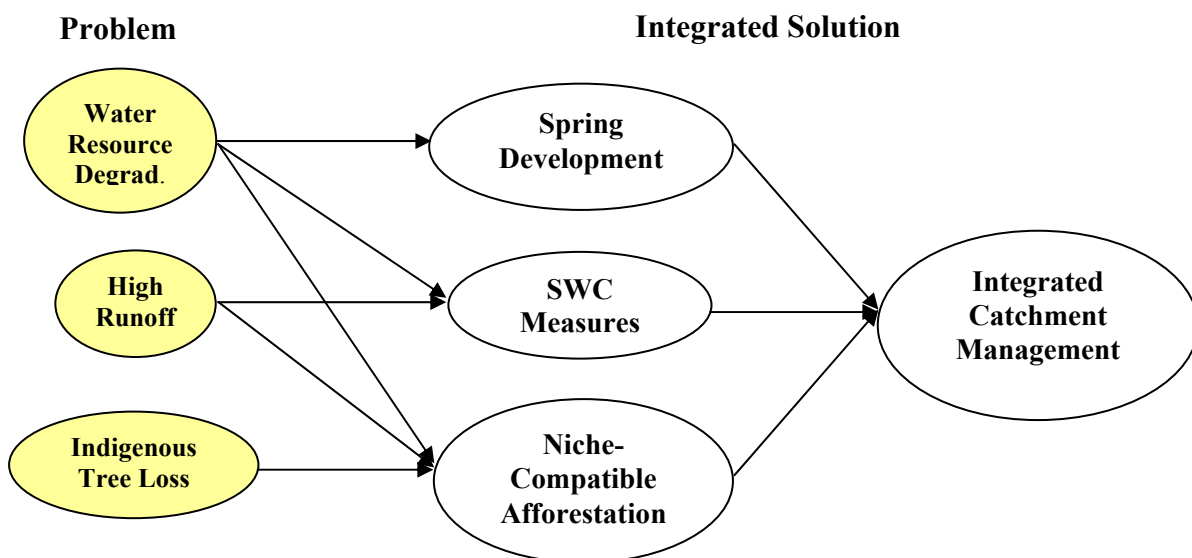


Figure 1. Schematic Diagram of a Clustering Process to Develop an Integrated R&D Agenda from Discrete Watershed Problems at Ginchi Benchmark Site

As implementation has advanced in the site, the need to break the research contribution down into its component parts (questions, variables, outputs) has become clear as researchers find it challenging to stay integrated. While fully integrated research objectives, questions, methodologies, outputs and outcomes were specified at the outset, the specific variables to be tracked were not identified. This gap led to a tendency to revert to component-specific research during implementation. This tendency stems from the desire for

individual ownership of research outputs, and reluctance of researchers to step outside of their scientific “comfort zone” to take an interest in and track variables lying within other areas of expertise. Table 4 results from an effort to clarify in greater detail how integrated research is operationalized at landscape level. The challenge is now to more systematically institutionalize integrated research protocols in all AHI sites.

CONSTRUCTIVIST INTEGRATION

Participatory Research in Barley Varietal Trials

The traditional staple crop in the Galessa highlands of Ethiopia is barley. Prior plant breeding efforts reflected the logic of maximization both in terms of component-specific goals (maximizing grain yield) and highly selective breeding to maximize yield of specific products (food barley vs. malt barley) – reflecting a strong researcher bias in decision-making. More recently, farmers’ priorities have been more systematically integrated into research at Galessa (Table 5). Emphasizing a logic of optimization, farmers give almost equal emphasis to grain yield and total biomass production when evaluating barley varieties (Bekele and Lakew, 2004). This reflects their interest in optimizing returns to crop and livestock components rather than the crop component alone. By tracking both variables simultaneously, researchers legitimize the multifaceted nature of farmers’ decision-making. Most importantly, these considerations can enter into basic research, in the selection of traits to be emphasized in subsequent plant breeding efforts.

Systematic consultation of farmers to formulate research objectives and isolate variables to be tracked has several important functions. The most obvious function is to highlight location-specific social, economic and cultural concerns. Yet equally important, identifying component-component relationships of greatest salience to farmers (in this case crop-livestock interactions that optimize returns to both components) highlights the most important variables in a systems approaches to research. This helps to simplify the task of the researcher in dealing with complexity.

Table 4. A Comparison of Non-Integrated and Integrated Research for Cluster 1

Aspect	Non-Integrated	Integrated (fostering component synergies in planning)
Research Questions	<ol style="list-style-type: none"> 1) Which tree species yield the most timber at Galessa? (tree) ^a 2) Which soil conservation structures are best for erosion control? (soil) 3) Which water structures protect water quality best? (water) 	<ol style="list-style-type: none"> 1) How can soil conservation structures, tree planting and drainage systems enhance agricultural production / productivity while minimizing erosion and enhancing spring recharge long-term? (tree, soil, water) 2) How can attention to water resources increase community enthusiasm for investments in activities with longer-term returns from catchment management ("","")?
Variables	<ol style="list-style-type: none"> 1) Timber yield of different species 2) Soil loss before/after structures 3) Water quality before/after spring development 	Spring discharge, water quality, soil loss, seed loss and fertilizer loss before/after interventions
Outcomes	<ol style="list-style-type: none"> 1) Trees with good timber yield but no benefits to soil, water, livestock 2) Soil and water conservation measures best for erosion; low adoption due to demands on labor/land/manure & benefits to soil only (not water or livestock) 3) Water structures that conserve water without stimulating farmer interest in agroforestry or soil conservation 	Technological interventions that optimize returns to agricultural production, soil conservation and water quality/quantity.

^a Italics denote the particular system components or dimensions researched.

Table 5. A Comparison of Non-Integrated and Integrated Research on Barley

Aspect	Non-Integrated	Integrated (Participatory)
Research Questions	What is the most productive food barley variety under conditions at Galessa? (<i>crop only</i>) ^a	1) Which barley variety gives a high yield of grain and good yield and quality of fodder under conditions at Galessa? (<i>crop and livestock</i>) 2) What are the trade-offs (effect on grain yield, culinary qualities for food and beer, fodder yield/quality, cost, income) of different varietal-nutrient management combinations at Galessa? (<i>crop, livestock, cultural, economic</i>)
Variables	Grain yield	1) Grain yield, fodder yield, nutritional value of fodder 2) Grain yield, fodder yield, nutritional value of fodder, inputs of labor/cash, market value at harvest, performance of local culinary indicators (<i>food, beer</i>)
Outcomes	Highest yielding variety at Galessa	1) Variety that optimizes gains to crop and livestock components at Galessa 2) Farmers are knowledgeable about what is gained and lost to crop and livestock components, culinary qualities, and the relative investments and returns, from different varietal-nutrient management combinations at Galessa

^a Italics denote the particular system components or dimensions researched.

Negotiating Benefits in Agroforestry: Seeking 'Win-Win' Outcomes through Niche Compatibility

Agroforestry tends to be treated as a largely technical enterprise, with social and environmental impacts assumed to be positive. Yet the interactions between trees and other system components (and resource users) are significant, and can be both positive and negative. In watershed diagnostic activities in four of AHI's benchmark sites, trees were found to exhibit a number of harmful properties – including competition with crops and negative effects on springs (including water discharge and taste) (German et al., in press b). These effects are exacerbated within certain landscape niches, and affect some local land users more than others. Tree planting and other land management practices must therefore be recognized as *inherently political*. Which species are chosen and where they are planted on the landscape have important implications for who gains and loses from (agro)forestry and which system goals (yield of timber vs. water, for example) are fostered. There is therefore a critical need to emphasize system compatibility in forestry and agroforestry research and practice, including both social and biophysical dimensions.

The need for an increased emphasis on system compatibility in agroforestry may be illustrated by a case study from Lushoto, Tanzania. Following identification of several tree-related problems, a more focused study enabled identification of four landscape niches requiring improved management: springs and waterways (6 incompatible species), farm boundaries (6 species), forest boundaries (2 species) and roadsides (3 species) (German et al, in press b). Yet many more species were found to be compatible with each of the four niches, offering an opportunity for optimizing gains to diverse system components and users in agroforestry.

Two trees were perceived by farmers to cause problems in all four niches: Mkaratusi (*Eucalyptus* spp.) and Mziaghembe (*Olea europea*). Eucalyptus is particularly interesting given the debates surrounding its ecological impact, and how it embodies contradictions between component and system-level objectives, individual and collective goods. On the one hand, Eucalyptus species are highly valued by farmers for their fast yield and quick economic returns and by the forest industry for their growth characteristics and yield of quality timber. This has led to the unqualified promotion of Eucalyptus for industry and smallholder farmers alike throughout much of eastern Africa. Yet on the other hand, they are perceived by farmers in all AHI benchmark sites to have the most harmful effect on adjacent crops and on water resources. The trade-offs between component and system-level objectives (trees vs. water, trees vs. multiple farm enterprises) are illustrated by the excellent performance of *Eucalyptus* spp. from a forestry perspective and their failure from all other disciplinary perspectives (livestock, soil, crop, water). The trade-offs between individual and collective goods illustrated by cultivation practices and effects. Landowners interested in cultivating Eucalypts push them to the far

reaches of their farms (tree lines or woodlots along farm boundaries) so as to minimize their interference with crops, while those fortunate enough to have springs within their farms cultivate Eucalyptus near springs to enhance growth rates. These practices have strong social trade-offs due to their negative impact on collective goods (water) and on the incomes of neighboring farmers.

The African Highlands Initiative has been developing an approach for multi-stakeholder negotiations in agroforestry to enhance niche compatibility in agroforestry. The approach consists of: (i) identification of social and environmental trade-offs of different species-niche combinations (what is gained and lost to different system goals and users by planting species x in niche y); (ii) stakeholder identification (who wins and who loses under the current scenario); (iii) negotiation support to forge socially-optimal solutions; and (iv) technological and governance mechanisms to enable more optimal species to be planted in prioritized niches.

From a research standpoint, integration involves moving beyond maximization within a single component (trees) and the unequal benefits induced by this approach, to optimizing system goals (production of *diverse* products, for example, or balancing biomass yields with nutrient and water conservation) to minimize harm to any given land user. Empirical research from both social and biophysical standpoints is required to understand what is gained and lost to different system components and land users from current agroforestry practice. Action-oriented research, on the other hand, is required to understand how the system might be transformed to enable more socially-optimal outcomes from agroforestry (Table 6).

Table 6. A Comparison of Non-Integrated and Integrated Research in Agroforestry

Aspect	Non-Integrated	Integrated (impacts on diverse land users made explicit)
Research Questions	Which tree species exhibit the best biomass yield in Lushoto? (tree – emphasizing economic benefits)	1) What are the social and biophysical trade-offs (effect on different land users and system components) of different tree species in different landscape niches (farm boundaries, springs, protected area boundaries, roadsides)? (crop – target and others, livestock, soil, economic) 2) How can more optimal agroforestry scenarios be forged?
Variables	Biomass yield of different tree species, timber quality (growth characteristics, etc.)	1) Yield of diverse tree products (timber, fuel, fodder, etc.); impact on other system components (crop yield, soil moisture, water discharge from springs, etc.); economic impacts on adjacent land users (labor costs to fetch water, income lost from decreases in crop yield, etc.). 2) Effect of different technological and governance solutions on the above variables.
Outcomes	Species with the highest timber yield and quality in Lushoto	1) Communities and local government are aware of what is gained and lost to different land users and system components when planting different tree species in select landscape niches, and are better able to target corrective measures for more optimal niche management. 2) Improved governance of agroforestry for more socially-optimal outcomes, including: (i) no appreciable harm accrues to other resource users from practices carried out by individual landowners); and (ii) optimized system goals (income generation with nutrient/water conservation).

SECTORAL INTEGRATION: OUTFIELD MANAGEMENT IN HIGHLAND ETHIOPIA

The need for sectoral integration is best illustrated through a case study on Ginchi Benchmark Site, located in the Galessa highlands in West Shewa Zone, Ethiopia. This site may be characterized as a mixed crop-livestock system and by its complex tenure system. Outfields, used for the cultivation of cereals and livestock grazing,

are individually owned but shift seasonally between restricted access (rainy season) and open access (dry season). From one year to the next, the use of any given outfield plot will shift from an individually cropped barley field to restricted-access grazing through the amalgamation of adjacent landholdings. Periods of free grazing (restricted and open access) complicate efforts to improve outfield productivity, as livestock consume what is left of crop residues and may trample trees and conservation structures. Coupled with perceived tenure insecurity and the absence of regulations on dung collection, this situation creates strong incentives to mine the outfields of nutrients (through the collection of dung and crop residues) and make natural resource investments only in the more secure homestead plots. As a result, outfields are almost devoid of trees and conservation structures and soil fertility has exhibited a steady decline that is exacerbated by increased use of dung for fuel.

Agricultural research and extension systems have tried to address these constraints through technological solutions emphasizing farm-level decision-making. As in the case of seed potato production, some of these efforts have been instrumental in raising incomes and encouraging soil fertility investments. However, most innovations emerging from this research approach are applied in infields (fenced areas close to homesteads) where tenure security is high, soil fertility is already excellent due to the proximity of households (where dung from nightly “parking” of livestock, household refuse and ash can be easily transferred to fields), and free-moving livestock do not pose a problem. Outfields remain barren and devoid of any perennials or long-term natural resource investments (Figure 2).

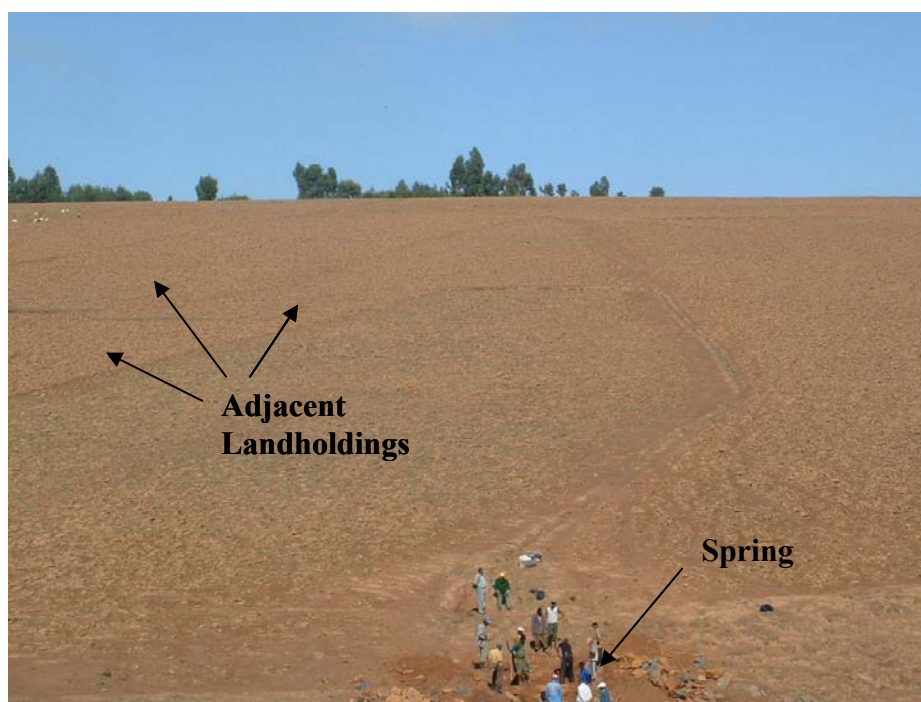


Figure 2. An Outfield at Ginchi Benchmark Site Illustrating the Absence of Conservation Investments (trees, soil conservation structures or spring protection)

While transformations in the productivity and sustainability of many highland farming systems can occur through farm-level technological innovations, for much of the Ethiopian highlands such an approach will be largely ineffectual. In the Ginchi case, outfield technological innovation is limited by the free grazing system. Trees cannot be established without continuous policing of outfield areas or costly investments in fencing – encouraging farmers to isolate small woodlots rather than creatively integrating trees into the cropping system. This tends to restrict the function of trees to the economic domain (provision of timber and fuel wood), foregoing many of the potential ecological benefits (soil and water conservation, soil fertility, etc). Soil fertility improvements are also hindered by the limited availability of fuel wood (causing a shift to dung for fuel), failure to regulate collection of dung (encouraging immediate scavenging of this resource), and the drive to collect all crop residues before free grazing sets in and this resource is diverted to neighboring farms. Options for integrating green manure or improved fallows into the system face both spatial and temporal constraints (with only 50% of outfields cropped during the rainy season, and the cropping season coming to an abrupt end once open access grazing initiates). Technological options for soil conservation are also limited by the damage

that would be caused by livestock during the establishment of structures or stabilizing vegetation, and further undermined by insecure outfield tenure. Intensification of the livestock system through the introduction of improved breeds and zero grazing principles has been largely unsuccessful due to the failure to develop a viable alternative feed supply – in particular for the dry season. Intensification of the livestock system must by necessity be gradual, beginning with a strategy for increasing the biomass in the system (with attention to alternative feed supplies) and gradually moving toward modified tenure regimes. As a result of these challenges, a national policy prohibiting free grazing is largely ignored throughout most of highland Ethiopia.

While the situation looks rather bleak, the coupling of technological innovation with social, policy and market interventions raises some interesting possibilities:

- *Social Interventions.* Social innovations have a critical role to play in forging a step-wise evolution and intensification of the system. Transformations in existing collective action institutions that regulate spatial and temporal dimensions of land tenure and grazing will be required to create a wider array of opportunities for technological innovation in outfields. Negotiation support can be employed strategically to identify such intermediate solutions collectively. It can also be employed to engage stakeholders that emerge from these negotiated solutions in collective decision-making on how to equitably distribute the costs and benefits of innovation among diverse households. For example, one option emerging from preliminary stakeholder dialogue in Ginchi is to temporarily restrict livestock movement in select areas of the watershed for a period of 2 to 3 years until outfield investments (trees, conservation structures, soil fertility innovations) can be established. This initial “testing site” would serve to validate technological innovations which would be subsequently scaled out to other parts of the watershed. Stakeholders emerging from this intermediate solution include landowners within and outside of the testing site, who become immediate and late beneficiaries, respectively. In addition to the differential rate at which benefits accrue to these two groups, their respective interests diverge due to unequal risks and benefits. While early beneficiaries must bear the weight of unsuccessful innovations, early innovators tend to benefit most from successful ones (Rogers, 2003). Furthermore, late beneficiaries must bear up-front costs of innovation within testing sites by allowing livestock of early beneficiaries to graze in their outfields. They also bear most of the risk associated with social innovations, given the possibility that early beneficiaries will fail to comply with agreements several years into the future.
- *Policy Interventions.* Policy interventions are also crucial for enabling intermediate and long-term shifts in outfield management. The most obvious role of policy is in enhancing tenure security in outfields so as to increase *incentives* for improved outfield management. While distrust of government policy stemming from prior land reforms and frequent shifts in political-economic system (feudal, socialist, capitalist) will shape farmer perceptions well into the future, efforts to strengthen tenure security nevertheless have an important role to play. Equally important, however, is to enable local policy reforms to give backing to resolutions reached through local negotiations. This will increase trust among stakeholder groups, for example by minimizing the risk of participation faced by late beneficiaries under the aforementioned scenario.
- *Market Interventions.* Market interventions also have a critical role to play as an incentive for intensification. Market solutions entered discussions, for example, when seeking ways to enhance economic returns from innovations in collective action institutions. Farmers are more likely to assume the risks associated with testing out temporary restrictions in livestock movement if they see concrete economic gains from doing so. In the absence of these social innovations, they are also more likely to invest in expensive fencing and policing efforts of individualized outfield innovations if economic returns are substantial. Given the climatic constraints at the Ginchi site and the integrated objectives of systems intensification (improved income *and* natural resource management), temperate and high-value fruit trees are seen as a potential “lever” for catalyzing system transformation. Yet it must be applied in conjunction with social and policy interventions in order to avoid loss of the conservation function of these trees.

Action-oriented research is needed to understand what works within diverse intervention areas (technological, social, policy, market), and how synergies among them propel system-wide change. The research can be operationalized according to the integrated parameters in the right-hand column of Table 7.

Table 7. A Comparison of Non-Integrated and Integrated Research for Outfield Management

Aspect	Non-Integrated	Integrated (multi-faceted, multi-sectoral approach)
Research Questions	Which technologies can increase soil fertility, system biomass, and productivity (crop, livestock) in outfields? (technological only)	Which technologies, local negotiations, market linkages, institutional reforms and governance arrangements are needed to enable increased soil fertility, system biomass and crop/livestock productivity in outfields? (technological, social, market, institutional, policy) What critical synergies emerge among these diverse interventions?
Variables	Soil nutrient stocks, biomass and yield calculations from diverse trials.	Soil nutrient stocks, biomass and yield calculations from diverse trials (technological); incidence of conflict, evidence of collective action, resolutions reached on technological and policy innovations (social); impact of high-value crops and trees on farmers' willingness to innovate (market); changes induced in local and external institutions to enable innovation, transformations in customary tenure institutions (institutional); proposed by-laws and their performance/modification as system innovation progresses (policy).
Outcomes	Technologies from diverse disciplines that are technically feasible but not adopted.	Positive synergies between technological, social, market, institutional and policy interventions propel system change in the direction of established (previously negotiated) system goals.

Discussion

DEALING WITH COMPLEXITY

One of the key challenges to embracing the integrated research concept is complexity. Researchers accustomed to highly focused objectives, variables and outputs that enable them to work within the confines of their particular disciplines will find it challenging to embrace these diverse forms of integration. This complexity must be embraced from two angles. First, researchers must be formally trained in systems perspectives to heighten the visibility of systems interactions and ramifications. Second, mechanisms must be developed to minimize complexity so that it is manageable. "Filters" that enable prioritization of critical interactions, and the variables that can most effectively capture these, are needed. Constructivist approaches provide a promising means to reduce complexity to a manageable level. Consulting key social actors can serve as a "filter" in the isolation of variables of greatest importance. Systematic consultation of farmers can serve as the first filter to simplify this complexity and elucidate the most critical variables to be tracked to optimize multiple system goals. Yet constructivist approaches also provide an opportunity for increasing the visibility of values of other social actors such as NGOs, local government, conservation organizations or other farmers likely to be affected by land use decisions inspired by research outcomes. Consultation of these other social actors on critical variables to monitor impacts of diverse options (technological or other) on sustainability, equity, biodiversity or other variables of interest can increase visibility of the consequences of land use decisions on other social actors and interests.

IMPLICATIONS FOR INSTITUTIONAL CHANGE

A fully integrated research paradigm would have profound implications for the structure, function, values and skill base of research organizations, with different types of integration having slightly different implications. Component integration would require interdisciplinary teamwork among existing biophysical disciplines; reorganization of research departments into interdisciplinary units structured around higher-level system challenges; reward systems for collaborative research; and moderate restructuring of university curricula to encompass new disciplinary perspectives such as systems and landscape ecology. Constructivist integration

would require stronger support to social science perspectives in formal training and staffing policies to bring in an emphasis on stakeholder analysis, negotiation support, “multi-site” approaches (Marcus, 1995) and other related skills, as well as incentives and funding for prolonged field work. Finally, sectoral integration would require more extreme shifts in the disciplinary balance of research staff to include marketing and policy specialists, facilitation experts and action researchers *in addition to* existing areas of expertise. It would also require institutional models for structuring partnerships between research and development institutions at diverse levels. Yet while the challenges to institutional change are substantial, these challenges pale in comparison to the potential for far-reaching impacts and innovations in research and development domains.

Conclusions

This paper presents an argument for an alternative research paradigm to strengthen synergies between research and development, development and conservation, and diverse disciplines and sectors currently working in isolation. Shortcomings of the current research paradigm include an emphasis on individual decision-making, farm-level analysis and component-specific objectives, and a logic of maximization that often undermines system goals. The paper highlights promising trends in research based on principles of participation, systems thinking and sectoral integration. However, it also highlights the need to strengthen emphasis on collective decision-making and landscape-level processes, and to go beyond the *technological* bias characterizing most agricultural research programs to more comprehensive *biophysical* innovation processes and the social, policy and institutional structures and processes in which these are embedded.

The paper outlines three integration concepts that can help to operationalize a more comprehensive research paradigm emphasizing optimization of returns to diverse system components, social actors and goals (i.e. livelihood and conservation). A series of five case studies illustrate how these integration concepts are operationalized in practice. Component integration can be fostered through an emphasis on prior anticipation of interactions among system components at farm or landscape scale which are made explicit in research questions, variables and outputs. It can also be enabled through ongoing and ex-post assessments of system-wide ramifications of technological and other forms of integration to better align researchers with system-wide goals and sustainability concerns. Constructivist integration, on the other hand, can be operationalized through standard participatory research processes (integration of farmers’ concerns into the definition of research objectives, methods and outputs), as well as through explicit consideration of diverse political interests in research design and in the wider application of research findings. Finally, sectoral integration can be achieved by ensuring that empirical and action-oriented research cuts across biophysical, social, policy and market spheres and seeks synergies among interventions in each.

The integration concept shows promise in enabling greater acknowledgement of the biophysical, social, political and institutional dimensions of natural resource management. However, strategies for managing complexity, and for enabling educational and research institutions to adapt their mandate, curricula and incentive systems, are fundamental conditions for operationalizing the approach within everyday practice.

Bibliography

- Atran, S. (1990) *Cognitive Foundations of Natural History: Towards an Anthropology of Science*. Cambridge: Cambridge University Press.
- Bashaasha, B. and J. Boesen (2004) Poverty Analysis in Integrated Agricultural Research for Development. *Uganda Journal of Agricultural Sciences* 9:23-30.
- Berlin, B. (1992) *Ethnobiological Classification: Principles of Categorization of Plants and Animals in Traditional Societies*. Princeton: Princeton University Press.
- Bekele, B. and B. Lakew (2004) Participatory On-farm Food Barley (*Hordeum vulgare* L.) Adaptation Trial in Ginchi Watershed Site of Ethiopia. *Proceedings of Integrated Natural Resource Management in Practice, ICRAF, Nairobi, 12-15 October, 2004*.
- Biggs, S. (1989). “A Multiple Source of Innovation Model of Agricultural Research and Technology Promotion,” AgREN Network Paper 6, ODI.

- Gebremedhin, W., A. Solomon, B. Kassa and E. Gebre (2004) Participatory Potato Technology Development and Dissemination in the Central Highlands of Ethiopia. Proceedings of Integrated Natural Resource Management in Practice, ICRAF, Nairobi, 12-15 October, 2004.
- German, L., S. Charamila and Tesema T. (in press a) Managing Trade-Offs in Agroforestry: From Conflict to Collaboration in Natural Resource Management. In S. Klappa and D. Russell (eds.), Transformations in Agroforestry Systems, Berghen Press.
- German, L., B. Kidane and R. Shemdoe (in press b) Social and Environmental Trade-Offs in Tree Species Selection: A Methodology for Identifying Niche Incompatibilities in Agroforestry. *Environment, Development and Sustainability*.
- Hagmann, J., E. Chuma, K. Murwira, M. Connolly and P. Ficarelli (2002) Success Factors in Integrated Natural Resource Management R&D: Lessons from Practice. *Conservation Ecology* 5(2):29.
- Lal, P. and H. Lim-Applegate and M. Scoccimarro (2001) The Adaptive Decision-Making Process as a Tool for Integrated Natural Resource Management: Focus, Attitudes and Approach. *Conservation Ecology* 5(2):11.
- Marcus, G.E. (1995) Ethnography in/of the World System: The Emergence of Multi-Sited Ethnography. *Annual Review of Anthropology* 24:95-117.
- Meinzen-Dick, R., A. Knox, F. Place and B. Swallow, Eds. (2002) Innovation in Natural Resource Management: The Role of Property Rights and Collective Action in Developing Countries. Baltimore: Johns Hopkins University Press.
- Rees, D.J. and M.P. Nampala (2004) Integrated Agricultural Research for Development: Achievements, Lessons Learnt and Best Practices. Conference Brief, 1-4 September, 2004. Entebbe, Uganda: NARO.
- Rocheleau, D. and D. Edmunds (1997) Women, Men and Trees: Gender, Power and Property in Forest and Agrarian Landscapes. *World Development* 25(8):1351-1371.
- Rocheleau, D., E. Wangari and B. Thomas-Slayter (1996) Feminist Political Ecology: Global Issues and Local Experiences. London: Routledge.
- Rogers, E.M. (2003). Diffusion of Innovations, 5th ed. New York: Free Press, 550 pp.
- Schroeder, R. A. (1993) Shady Practice: Gender and the Political Ecology of Resource Stabilization in Gambian Garden/Orchards. *Economic Geography* 69(4):349-365.
- Starks Acosta, A., M. Jones and R. von Kaufmann (2005) The Sub-Saharan Africa Challenge Program: An Experiment in Mainstreaming Institutional Learning and Change. ILAC Brief 9.
- van Noordwijk, M., T.P. Tomich and B. Verbist (2001) Negotiation Support Models of Integrated Natural Resource Management in Tropical Forest Margins. *Conservation Ecology* 5(2):21.

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The AHI Working Papers Series was developed as a medium for AHI staff and partners to synthesize key research findings and lessons from innovations conducted in its benchmark site locations and institutional change work in the region. Contributions to the series include survey reports; case studies from sites; synthetic reviews of key topics and experiences; and drafts of academic papers written for international conferences and/or eventual publication in peer reviewed journals. In some cases, Working Papers have been re-produced from already published material in an effort to consolidate the work done by AHI and its partners over the years. The targets of these papers include research organizations at national and international level; development and extension organizations and practitioners with an interest in conceptual synthesis of “good practice”; and policy-makers interested in more widespread application of lessons and successes.

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