Searching development strategies for less-favoured areas

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Abstract

Rural households in less-favoured areas (LFAs) face multiple constraints for overcoming chronic poverty and resource degradation. Strategic development options can be assessed through interdisciplinary research based on coupling of human and natural systems approaches. Simulation modelling enables the identification of more precise research questions and the definition of appropriate fieldwork methods. We present an overview of the stylized micro-macro modelling framework used for the exploration of production and resource management options and livelihood strategies at household and village level. The simulation outcomes are subsequently used for the identification of feasible pathways for agricultural and rural development in LFAs and for critical incentives that enable households to invest in profitable and sustainable resource management. The interaction between model simulations and topical field research generates useful insights for the design of comprehensive research programmes regarding strategies for sustainable development in LFAs. Stylized models of coupled human–natural systems based on the behaviour of representative stakeholders provide a practical and flexible framework for exploring critical research issues.

Additional keywords: micro-macro modelling, coupled systems, research strategy

Introduction

Poor people living in less-favoured areas (LFAs) represent globally around 40% of the rural population suffering from chronic poverty. LFAs are defined as remote regions with a limited natural resource base (given the population), where problems of chronic poverty and resource degradation tend to coincide. Given their scarce agricultural potential and difficult access conditions, standard devices for enhancing rural development cannot appropriately address issues of poverty alleviation and sustainable natural resource management. Escaping from the downward spiral of poverty and resource degradation asks for the identification of suitable pathways enabling rural households to develop production systems and livelihoods that respond to local conditions (Pender *et al.*, 2001; Pender, 2004; Hazell *et al.*, 2005).

The diversity in agro-ecological settings and the heterogeneity amongst rural households pose particular challenges to rural development. Instead of a *one-size-fits-all* strategy, a far more targeted approach is required to exploit the comparative advantage of different resource management strategies for particular types of households and communities (Ruben & Pender, 2004). Moreover, attention needs to be paid to the incentives and governance regimes that enable farmers to adjust their production systems and livelihoods in order to guarantee both welfare and sustainability objectives. Identifying the right combination of public and private investment efforts oriented towards sustainable intensification of farming systems and rural livelihoods is of fundamental importance for attaining such win-win options.

This article provides an overview of the interactive research approach used for the definition of relevant research topics within the framework of the collaborative research programme on *Regional Food Security Policies for Natural Resource Management and Sustainable Economies* (RESPONSE). This programme is jointly managed by the Graduate Schools for Social Sciences and Production Ecology and Resource Conservation of Wageningen University (The Netherlands) in co-operation with the International Food Policy Research Institute (IFPRI) at Washington D.C. The programme aims to identify strategic options for agricultural and rural development in less-favoured areas and policy instruments that enhance rural household's investments in improved and sustainable natural resource management. Fieldwork is conducted in different less-favoured area settings in eastern Africa (Ethiopia, Kenya, Uganda) and South-East Asia (Bangladesh, Philippines, China) in co-operation with local partner institutes.

The RESPONSE research approach relies on the interaction between prototype modelling and local field work in order to be able to select appropriate research domains and to provide orientation for more detailed studies focusing on critical issues. We developed a stylized bio-economic farm-household and village modelling approach to assess the likely responses of different types of rural households to technical, economic or institutional incentives for resource use intensification (Kruseman, 2000; Kuiper, 2004). The model considers asymmetric access to factor and output markets and can thus be used to identify production and consumptive responses and within-village interactions. This prototype micro-macro model with stylized data is applied to identify particular research questions for the cohort of PhD students participating in the RESPONSE research. The programme is structured in different working programmes that focus attention on particular strategic options for improving household welfare and sustainability of natural resource management regimes.

Development pathways for less-favoured areas usually demand careful adjustment of resource use strategies at field, farm-household and village level, looking for a portfolio of activities and technologies that guarantee input efficiency and labour productivity. The simulations can be helpful to review the implications of asymmetric market access for income inequality and resource degradation and the potential pathways for escaping spatial poverty traps in less-favoured areas. Targeting of incentives towards resource-poor households can be required to guarantee simultaneous increase in the returns to land and labour. Otherwise, institutional strategies for reducing transaction costs tend to be critically important for enhancing investments and enabling income diversification. Starting from this generic modelling framework we identify specific problem areas that need to be addressed within the research programme.

Setting

Research conducted within the framework of the RESPONSE programme is focused on less-favoured areas in developing countries. Remoteness and resource scarcity in these areas lead to severe problems of chronic poverty and resource degradation. Scarce market linkages and institutional failures reduce the effectiveness of agricultural development instruments. Under these conditions, rural households organize their livelihoods through selective engagement in a wide number of (non-)agricultural activities to cope with uncertainties and diversify risk.

Production systems and livelihood strategies in the LFAs are highly diversified, based on the combination of different cropping, livestock and non-farm activities and relying on strong interactions among agricultural activities (e.g. crop residue recycling, animal traction for land preparation, manure deposition). Resource use strategies need to make optimal use of the spatial heterogeneity amongst farmers' fields. In most highland areas in eastern Africa and South-East Asia, rural households suffer from low land and labour productivity and investment barriers that inhibit the take-off towards a process of sustainable agricultural intensification (Pender, 2004). In the dry areas of Sub-Saharan Africa, this process is further constrained by the strong variability in rainfall conditions, which ask for highly adaptive farming strategies (Dietz *et al.*, 2003; Ruben *et al.*, 2003). In both settings, local non-market arrangements play an important role in overcoming temporal resource constraints. Most important structural features that characterize farm households behaviour in such LFAs can be summarized as follows (Ruben & Pender, 2004):

- relatively 'simple' production technologies making intensive use of locally available production factors;
- strong local interactions between households based on exchange of inputs, labour and consumptive commodities;
- limited savings (mainly for consumption smoothing) and low fixed investments due to high risk and binding cash or credit constraints;
- large price bands between farm-gate and market prices and market entry barriers due to high transaction costs that reduce the tradability of agricultural commodities.

In addition to these general constraints to agricultural and rural development, communities located in LFAs are characterized by a particular social structure with a strong heterogeneity in farm household resource endowments, ranging from landless workers to better-equipped farmers (Hazell *et al.*, 2005). Household-specific transaction costs tend to limit access to input and output markets, whereas institutional arrangements may lead to a differential access to common property resources (pasture and forestry areas). This implies that farmers face different constraints for contributing to the resource conservation activities at farm and village level required to control externalities.

Given the variability amongst LFAs in terms of their agricultural potential (soil fertility and rainfall) and access (remoteness), different types of development options can be identified for addressing poverty and resource degradation (see Table 1). Instead of focusing on resource use intensification only, LFA development asks for simultaneous efforts in the directions of production systems integration, searching for input complementarities, activity diversification and selective market integration. Given the conditions of spatial remoteness and agro-ecological marginality in LFAs, downward spirals of poverty and resource degradation are frequently observed (Cleaver & Schreiber, 1994; Leach *et al.*, 1999). Chronic poverty and access constraints tend to inhibit farmers' willingness and ability to invest resources and efforts for overcoming the generally low factor productivity. The interlocking of socio-economic, physical and demographic factors causes a path-dependency characterized by the coexistence of diverse livelihood strategies and resource management regimes (Woods & Cook, 2003). The particular setting that characterizes farmers and villages within LFAs implies that strategic research should simultaneously address the production, consumption and resource constraints faced by specific categories of households and

Table 1. Development options for different settings of market access and agro-ecological potential.

Agro-ecological potential	Market access	
	High	Low
High	*High-potential areas* (e.g. central Kenya; eastern China) Focus on options for intensification and activity diversification (including non-farm employment).	*Remote less-favoured areas* (e.g. much of East African highlands; parts of South-East Asia) Focus on production for local use and high-value tree crops, possibly combined with (temporary) migration.
Low	*Marginal less-favoured areas* (e.g. North Africa; semi-arid areas in India and China) Focus on commercial niche activities and semi-intensive livestock, combined with off-farm work in urban areas.	*Remote and marginal less-favoured areas* (e.g. much of the arid and semi-arid parts of Africa) Focus on integrated and low external input systems, resource conservation and emigration.

need be tailored towards the opportunities provided within the institutional context of local communities and thin markets.

Outline of the stylized less-favoured-area model

A prototype micro-macro model is developed to identify specific research questions. To stress the generic character of the prototype model we relied on stylized data. This allows us to provide outcomes corresponding to typical features characterizing less-favoured areas and to focus the discussion on general patterns as opposed to case-specific issues. The main objective of starting from a generic model is to facilitate discussion among the different disciplines involved in the RESPONSE programme. The model aims to provide a common reference point for identifying prospective research questions that deserve to be further explored in subsequent field studies.

The prototype micro-macro model builds on earlier advances in bio-economic farm household modelling (Kruseman, 2000) and village equilibrium modelling (Kuiper, 2004). The model links a set of household models into a village equilibrium model. Setting households in a village environment allows an analysis of interactions among households, through local market exchange or the reliance on common property resources. In the following, we provide an outline of the structure of the LFA modelling framework and discuss how the stylized model can be helpful for the selection of relevant research topics. Hereafter we highlight some preliminary model results that serve as research guidance for the discussions on rural development strategies in LFAs.

The structure of the micro-macro simulation model is based on four components: (1) a system of production functions with alternative input requirements and output levels, (2) a specification of consumption decisions allocating income to commodities, leisure and savings, (3) a set of price equations determined by household supply and demand defining whether commodities are home consumed, bought or sold, and (4) commodity balances specifying that commodity use cannot exceed availability. For the model specification see Appendix 1.

The model has been stripped to the bare essentials needed to capture the core of household decision-making in less-favoured areas. Socio-economic diversity is included by distinguishing four household groups – landless, small farmers, medium farmers and large farmers – with different factor endowments (see Table 2). The stylized village consists of a total of 100 households, of which the medium (50) and small (30) farm households are the largest groups. The poorest two household groups have the largest family size and the smallest land endowment. Two different measures of household income are used: full income (value of consumption at household-specific shadow prices) and consumption expenditures at market prices (i.e., without accounting for price-bands). The latter measure provides a household-independent indicator of welfare.

The aim of the stylized model is to provide a flexible analytical framework that can be easily adjusted to different settings. Therefore, all model equations are defined with generic sets of factors and goods, covering inputs, outputs, consumed goods, goods

Table 2. Endowment factors and incomes of the four household groups.

	Landless	Farmers		
		Small	Medium	Large
	(n = 10)	(n = 30)	(n = 50)	(n = 10)
Endowment factor [1]				
Labour	6.0	6.0	5.0	4.0
Cropland	0.0	0.5	1.5	2.5
Marginal land	0.0	0.5	1.0	0.5
Pasture	0.5	0.5	2.5	5.0
Household income				
Full income	1.4	1.6	3.3	5.0
Consumption expenditures at market prices	3.7	4.3	6.2	7.8

[1] Labour in adult equivalents; land endowments in ha.

Table 3. Assumed activities, commodities and set membership in the base model [1].

	Inputs	Outputs	Consumption	Household tradables	Buying price	Selling price
Staple crop		×	×		×	×
High-value crop		×	×		×	×
Livestock products		×	×		×	×
Manufactured good			×		×	
Labour	×		×			
Cropland	×			×		
Marginal land	×			×		
Pasture	×					
External inputs	×				×	
Savings			×		×	

[1] Table reflects tradability in the base run; set assignments are changed in different simulations.

that are traded without price bands (household tradables) and goods that are traded with price bands and thus have different buying and selling prices. By assigning a factor or good to specific sets, key assumptions regarding the presence or absence of markets or technologies can be changed without having to adjust the modelling framework.

Table 3 provides a listing of the assumptions in the base model. The first three rows indicate that three products are produced (staples, high-value crops and livestock) that can be consumed by the household or traded at the market against different buying and selling prices. Households also consume manufactured goods that have to be purchased at the market, but cannot be sold again. Labour is used as input in production and consumed as leisure, but cannot be sold or purchased. We suppose the absence of village labour markets and thus exclude options for local off-farm employment. Given the high monitoring costs of non-family labour we assume that instead of labour markets, village land markets provide for an efficient allocation of resources across households (Ahn & Faith, 1996). We also abstract from different types of share-cropping arrangements, assuming monetary payments for land. In subsequent model simulations, we relax both assumptions in order to identify the possible impact of pasture exchange and outside migration for farm household resource use and welfare. An important assumption in the base model is the non-tradability of pastures, which we consider allocated to the households by village authorities.

Parameters for base-level consumption are derived from expenditure shares and income elasticities observed in low income countries (Anon., 1996). In the model applied, consumption expenditures shares shift with changes in income. The expenditure pattern of the households in the stylized model thus depends on their income level, with poorer households spending a larger share of their income on food. Parameters for the production technologies are derived from Constant Elasticity of Substitution (CES) production functions, following the procedure outlined by Löfgren & Robinson (1999). Appendix 2 summarizes the base level consumption and production parameters by agricultural activity to provide an indication of the differences across activities in terms of income share and input use.

For all production activities a range of alternative technologies is specified with different combinations of land, labour and external inputs. For staple and high value crops alternative technologies that require less external inputs are defined. This allows cash-constraint households to produce crops, using only land and labour. We relate heterogeneity directly to differences in comparative advantage regarding resource management strategies for particular types of households and communities. These are reflected in the model through: (1) four specific categories of households with typical factor endowments, (2) household-specific transaction costs (price bands), and (3) different propensities to save. We consider this dis-aggregation at this stage sufficient to account for both biophysical and behavioural heterogeneity.

Identifying research directions for less-favoured areas

The modelling framework outlined above is used to identify a number of key research issues that can be considered of critical importance for overcoming the poverty-environment deadlock that typically prevails in most LFAs. We explore four major research directions that should be systematically addressed in order to be able to overcome some of the constraints to rural development in LFAs. These research issues are further analysed through the adjustment of relevant model parameters and the derived implications with respect to their incidence on poverty alleviation and for the sustainability of the natural resource base.

We applied different shocks to the base model in order to find out which model components are essential for generating changes in household performance. This procedure enables to verify the sensitivity of the model results to parameter adjustments. The selection of the parameters is done in such a way that they represent different intervention strategies. To maintain a clear focus in the analysis, each strategy is based on a partial appraisal of the effects of only one specific parameter change compared to the base run.

The first research issue refers to land tenure as a possible constraint for enhancing agricultural productivity and food self-sufficiency. Given the coexistence of individual and collective fields within the villages, land use and agricultural production on common fields tend to be far less resource-intensive, since farmers are likely to exhibit free-riding behaviour (Meinzen-Dick *et al.*, 2002). This implies that farm households rely on different sets of technologies for producing commodities on their own or on village fields. Village authorities, however, try to provide incentives or set rules to control overexploitation and degradation of the common fields. In addition, farmers themselves might be motivated to implement soil conservation activities in common fields to control for negative externalities (erosion, run-off). Finally, differential access to common fields – levying household-specific use fees for livestock or forestry purposes – can be used as a device for reducing welfare inequality within villages (Deininger, 2003).

The second research area focuses on consumption behaviour. Poor households tend to rely on consumption smoothing strategies in order to guarantee stable availability of food, relying on adjustment in their capital resources or savings to balance temporal income shortfalls (Morduch, 1995). Although such behaviour is usually analysed in an inter-temporal framework, short-term consequences for the asset base can be reviewed also with the current model. We therefore analyse the implications of alternative sets of saving propensities for income distribution and resource use intensity. This could be helpful to reveal the importance of local or external insurance regimes for enabling households to maintain consumption smoothing without affecting the sustainability of natural resource management (Skees *et al.*, 1999).

In the third research area the options for activity diversification are further analysed. It is commonly assumed that diversification of activities could be helpful to reduce the vulnerability of the farm household economy (Reardon, 1997; Bryceson, 1999). Further engagement in off-farm employment and the availability of remittances from migrant labour tend to be very useful for overcoming cash constraints. In most LFAs, high transaction costs tend to enhance subsistence production and reduce the possibilities for finding work on the labour market (De Janvry *et al.*, 1991). Migration can thus be a mitigating device for overcoming poverty and resource degradation in LFAs, enabling rural households to rely on more purchased external inputs to improve their farm and non-farm activities.

The fourth research area considers trade integration and limited infrastructure as a core constraint and reviews the implications of reducing the price bands. With further market engagement of farmers and villages, price transmission towards LFAs may be favoured through improvements in physical and communication infrastructure (Dercon, 1995; Blauch, 1997; Barrett, 2001). Reductions of the price bands between farm gate (sales) price and market (purchase) price are expected to enable farmers to increase their market participation reviewed, even while different types of household types may exhibit differences in supply responsiveness. Supportive measures to enhance supply response of resource-poor farmers may be required in order to prevent a deterioration of income distribution and to control for resource degradation.

The selected research areas together represent a coherent framework for the analysis of the potential reactions of rural households to changes in the socio-economic and/or institutional environment. The technical and environmental implications of different strategic parameter adjustments are visualized as endogenous responses to human behaviour. The identified issues provide a clear structure to the research programme and permit a stylized framework for identifying the available margins for enhancing food security and sustainable resource management through reforms in governance or market regimes.

Model outcomes for research guidance

The stylized modelling framework is used to gain insight into the likely adjustment behaviour of different categories of households under changing socio-economic conditions. At this stage, the model simulation results can serve as research guidance in discussions on prospective rural development policies for LFAs. The model parameters outlined in Table 4 are used to generate alternative scenarios. Tables 5 and 6 provide the results for consumption and production behaviour, reporting changes in income and expenditures, and adjustments in (non-)agricultural output compared with the base run. The four alternative conditions ('tenancy' etc.) correspond to the four strategic options mentioned in Table 4. The impact on sustainability is assessed through two indicators: (1) pressure on land measured by the share of available marginal land taken into cultivation, and (2) reliance on externally purchased inputs (see Table 7).

Only smaller price bands, representing better market access, improve income for all household groups, although especially benefiting the resource-poor households that are net buyers of food. Since these poorer households tend to face most binding credit and investment constraints, engagement in off-farm employment is the most attractive device to improve their income. The earnings from off-farm employment allow the poorer households to switch to higher productive technologies that require more external inputs. Note that off-farm employment has an especially strong effect in terms of full income, which represents the increased scarcity of labour. In terms of expenditures at market prices the income increases are more modest. Also note that the larger households are negatively impacted by the availability of off-farm employment options. This is the result of an indirect effect through the village land rental market. The availability of off-farm employment offers the poorer households with more labour but limited land endowments the possibility for activity diversification. Consequently, poor households' demand for land decreases, resulting in a net decrease in cash income from renting-out land for the richer households. Measured in terms of expenditures this negative impact on cash income outweighs the positive impact of alternative income sources derived from off-farm employment.

Table 4. Strategic options and model parameters used for generating alternative scenarios.

Model parameters	Strategic options			
	Land tenure regime	Consumption smoothing	Diversification of activities	Market access
Village exchange of pasture land	Household tradable	Household non-tradable	Household non-tradable	Household non-tradable
Increasing marginal propensity to save	All households 0.09	Landless and small households 0.18	All households 0.09	All households 0.09
Engagement in off-farm employment	No off-farm employment	No off-farm employment	One member working outside the village	No off-farm employment
Reduction of price bands	0.75 for all commodities	0.75 for all commodities	0.75 for all commodities	Reduced by 10% for all commodities

Table 5. Changes (%, relative to base run) in full income and expenditures.

	Landless	Farm			Village
		Small	Medium	Large	
Full income					
Tenancy	41.8	33.1	–8.2	–3.5	2.5
Smoothing	–0.2	–0.1	0.1	0.2	0.0
Off-farm	123.6	99.4	11.0	–4.3	29.6
Price bands	29.3	25.4	4.2	11.0	10.5
Expenditure valued at market prices					
Tenancy	15.0	8.0	–1.6	10.0	3.2
Smoothing	–1.1	–1.6	0.0	0.0	–0.4
Off-farm	34.9	20.9	–9.7	–4.3	1.3
Price bands	8.9	5.4	1.1	2.9	2.9

A similar distribution of welfare effects in favour of poorer households results from tenancy reforms, since improved access to pastures will allow them to expand livestock production and become self-sufficient in livestock products. At the same time possibilities of renting-in pastureland reduce their demand for crop and marginal land. The

Table 6. Changes (%, relative to base run) in produced agricultural output.

	Landless	Farm			Village
		Small	Medium	Large	
Tenancy					
Staple crop	11.4	–21.6	0.2	15.1	–4.6
High-value crop	12.5	5.8	0.7	18.8	4.7
Livestock	122.0	72.2	–25.8	–76.0	1.0
Smoothing					
Staple crop	–0.9	1.8	–0.1	–0.1	0.5
High-value crop	–2.0	–3.0	0.0	–0.1	–0.9
Livestock	7.3	–1.8	0.0	0.0	0.2
Off-farm					
Staple crop	23.3	–16.5	–10.8	–2.0	–9.4
High-value crop	26.2	13.5	–11.5	–2.1	–1.4
Livestock	–12.8	–21.4	–6.1	0.0	–9.1
Price bands					
Staple crop	7.1	32.2	–0.8	0.4	10.5
High-value crop	7.1	3.5	1.4	0.3	2.2
Livestock	11.6	–17.1	2.4	0.0	–1.7

net impact of reduced cash income from renting-out cropland and increased inflow of cash from renting-out pasture land differs between the medium and large household. The net gain of cash income (allowing to finance external inputs) of the large household is due to their larger endowment of pasture. So the interactions within the village and the resource base of households play an important role for the impact of policies on different household types, calling for a targeted approach instead of a *one-size-fits-all* strategy.

Finally, enhancing consumption smoothing through improved savings prospects for poor households does not overflow to the other two household groups. For the poor households it does require a re-direction of their resources to generate the cash needed for the savings. This reduces their current welfare as measured by their expenditures (that includes savings).

The adjustments at the production side are particularly strong for livestock activities under the tenancy reform simulation (see Table 6). The reform reduces a factor market imperfection, which is reflected by the increase in livestock production at village level. The large households are the major suppliers of pastures to the poor households, using the income earned to intensify crop production relying on external inputs. Different production shifts of poor households with consumption smoothing are due to specific endowments. The landless household only has an initial endow-

Table 7. Changes (%, relative to base run) of sustainability indicators at village level.

	Marginal land		External inputs
	Used for agriculture [1]	Village price	
Tenancy	0.0	−37.4	52.7
Smoothing	0.0	0.2	0.0
Off-farm	−1.2	−100.0	177.0
Price bands	0.0	−14.1	100.0

[1] In the base run all available marginal land is used for agricultural production.

ment of pasture land, and thus relies on intensification of livestock production. The small household intensifies staple crop production, which, due to the lack of cash resources for purchasing external inputs, generates most output per unit of its (abundant) labour.

The off-farm employment scenario introduces a source of cash income, which is used by all households to increase the use of external inputs. For all except the large household, this implies a shift in technology since they do not use any external input in the base run. The availability of cash income allows the poor households to diversify into high-value crops and intensify production. In contrast, the medium household reduces all its agricultural activities. It can compensate the reduced income from renting-out cropland by working off-farm, but this increases the scarcity of labour of which this household has a limited endowment. Finally, increased market access through lower price bands in commodity markets generates better options for engaging in high-value crop production for all households.

The above-mentioned shifts in consumption and production strategies have direct implications for the sustainability of the village-level resource base (see Table 7). Although dynamic effects of resource degradation are not accounted for (in a one-period model), the dis-aggregation of the resource base in land suitable for different purposes (see Table 3) provides information on (1) the pressure on marginal land, and (2) the increasing reliance on external inputs for maintaining resource productivity. Engagement in off-farm employment limits the demand for land, enabling households to take part of the marginal land out of production. Since in all other scenarios all available marginal land is used, Table 7 also includes the village price as an indicator of the pressure on marginal land. This indicates that the generation of additional savings in the consumption-smoothing scenario increases the pressure on marginal land. In the longer term, however, investments from savings might have positive sustainability effects. Other scenarios involve a diversification of activities, thus reducing the pressure on marginal land. In the reduced price-band scenario, for example, the improved market access enables the use of external inputs, improves resource use efficiency and reduces the reliance on vulnerable land resources. The use of external inputs in this scenario, however, is limited to fields of the medium and large households. For the landless household the benefits of an increased market access may be at the expense of sustainability. The restricted access to cash income coupled with a large labour endowment induces this household to rent-in mainly marginal land while it does not use any external inputs.

Drawing some general lessons from the presented simulation outcomes we can conclude that the stylized modelling framework provides a useful tool for analysing simultaneous adjustments in production, consumption and labour strategies under various market and institutional conditions. The outcomes give insights into the binding constraints for sustainable development in LFAs and the model provides information on the changes in resource allocation (land use shifts and technology choices) that are induced by different conditions of market access and exchange. Moreover, the outcomes show sufficient sensitivity to conclude that the model can be a useful explorative tool for guiding further field research.

Research topics

The RESPONSE approach is based on a combination of prototype modelling under the stylized LFA conditions, followed by a series of local studies focusing on particular aspects of the production, consumption or exchange conditions prevailing in the fieldwork locations. The interdisciplinary aspect of the research approach is based on coupling of human and natural systems in order to enable the identification of key constraints. We relied on an interactive approach to bio-economic modelling (of which the above model is a further elaboration) as a tool in the research process for comparing concepts and identifying structural relationships emanating from different disciplines and traditions. The model framework allows the creation of a common understanding and communication between scientific disciplines regarding the required data sets, the expected relations and causalities, and the relevant feedback mechanisms (Gibbons *et al.*, 1994). Such discussions permit to identify common ground between social and natural scientists regarding the underlying causes of resource inefficiencies, the constraints to food insecurity, and the driving forces of environmental degradation. The analytical framework is based on the linking of socio-economic and agro-ecological modules for analysing interactions between human and natural systems. Instead of the formal integration of different types and categories of models, more loosely coupling procedures are applied based on simple algorithms that represent underlying processes. This implies disassembling separate systems or modules (i.e., production and consumption strategies) into their functional components (i.e., input use and expenditures) and joined together to composite services (i.e., sustainability and food security) to create a framework for subsequent analyses of the systems dynamics. This approach can be particularly useful to relate vulnerability concepts from natural science with coping behaviour in social systems (Beekun & Glick, 2001). So understanding the evolving linkages within coupled human-biophysical systems is critical for understanding the adaptation in livelihoods and production systems. This approach can be useful to derive testable hypotheses with respect to key variables that affect patterns of interactions, like the type of market organization, the access to technologies, and the environmental implications.

In the initial stage, the model is used for the identification of core research issues, but in-depth studies of these issues are subject to more detailed analysis by specific researchers. In subsequent phases the results of the topical field studies can be confronted with the outcomes of the model simulations. The latter comparison should lead to a further refinement of the model. This procedure enables the development of a more precise analytical framework that can be used to evaluate the prospects for scaling up of locally specific outcomes to wider recommendation domains.

Here we focus on the first step in the analytical procedure where alternative model simulations are used for identifying relevant fieldwork topics in selected research sites. The fieldwork is currently underway and therefore only preliminary results are available. The thematic field research permits, however, to reflect on the critical components and parameters underlying the model. This may also provide useful insights regarding appropriate areas for policy intervention. Otherwise, locally specific outcomes that deviate from the model simulations make room for improvement of critical relations in the model specification. The comparison of model outcomes and fieldwork results enables to identify the following key aspects for further research regarding suitable investment strategies for efficient and sustainable resource management in LFAs.

Sustainable resource use

Understanding the driving forces for resource use decisions represents a key research area. The simulation results prove to be particularly sensitive to the input-output production coefficients and the price band parameters. Empirical field work in northern Ethiopia and eastern China focuses on the interface between farmers' resource use decisions influenced by the available set of technical options and the market relationships. In addition to these factors, farmers' risk behaviour appears to be a variable that plays an important role in the resource use decisions (Fafchamps, 2004).

Another assumption that needs further empirical assessment refers to the differences between access and availability of alternative technologies. The base model does not consider differences in technical knowledge and abilities, whereas in practice not all land use options are equally available to each household. Since all households have access to the same technologies, choices for different technologies by different households are driven by resource endowments. Important differences in adoption behaviour need to be understood in relation to the spatial location of plots (fieldwork in China) and the human and social capital endowments of farmers (fieldwork in the Philippines and Ethiopia). It appears that there is still limited understanding how adoption of alternative technologies actually takes place and which household characteristics (like age, gender, education) play a decisive role in this process. Insights derived from adoption and innovation studies (Feder *et al.*, 2004) can be helpful to improve the model specification in this respect.

An additional interaction between the biophysical and the socio-economic realm that deserves attention refers to the input complementarities and synergy effects between cropping and livestock activities. Nutrient flows between crop and livestock systems can be of vital importance for maintaining stable yield levels and are therefore studied in detail in northern Ethiopia (Hengsdijk *et al.*, 2004). However, accounting for such interactions proved to be rather difficult in a modularly designed framework. Since field studies confirm the critical importance of this variable, a more detailed assessment of the impact of adequate timing of input applications on yield levels is required (Kruseman, 2006).

Poverty and livelihoods

Model outcomes regarding the responses to institutional change and market reforms ask for further research concerning the adaptive behaviour of rural households in LFA settings. The dynamics of consumption smoothing is only partially captured by the discount rate parameter. More detailed field studies in Bangladesh using panel data are undertaken that compare individual savings with other social insurance mechanisms and could reveal the role of rural micro-finance institutions for guaranteeing stable consumption. So a more dynamic representation of the smoothing mechanism is required to provide the link between consumption behaviour and the available assets (Deaton, 1992).

The model outcomes regarding the role of off-farm employment generally confirm the importance of binding credit and investment constraints for overcoming rural poverty (Barrett *et al.*, 2001; Zeller, 2003). Although the model adequately captures the implications for the reduced labour intensity of production systems and the expenditure effects of off-farm work, additional field research is undertaken to understand whether and how differences in risk attitudes might still inhibit farmers to diversify their activities (Anon., 2004).

Rights and risk

The model simulations indicate that institutional regimes perform a critical function for resource allocation decisions. This is particularly clear from the simulations regarding land tenure regimes and market access. The stipulated relations between changes in land tenure and crop and technology choice disregard possible behavioural implications of improved ownership rights, like the higher willingness to invest and the improved input efficiency on own plots (see Otsuka & Place, 2001). In addition, collective action effects derived from improved land right regimes need to be included (Meinzen-Dick *et al.*, 2002).

The generally positive results of the simulation with reduced price bands need further research. More detailed studies in China are undertaken to understand why market liberalization does not automatically lead to more competition and therefore lower price bands do not always reach the farm gate. Moreover, field research in Ethiopia addresses the mechanisms for price transmission that appear to be different for specific categories of households (Negassa, 1998). This points to the importance of linking the village model to a macro-economic framework in order to address the interactions between global policies and local development (Barrett & Carter, 1999).

Markets and resources

The modular framework for analysing production and consumption decisions can be helpful to analyse the role of internal and external resources in strategies for sustainable poverty alleviation. Loose coupling of human and natural processes provides useful insights into the binding constraints in one particular realm that impose limitations on another realm. This is particularly the case when either resource endowments or access constraints reduce production or consumption levels. So further research is scheduled to address the entry conditions into higher value market segments (in Ethiopia and China) in order to understand under which particular conditions rural households are able to invest in market-oriented diversification activities.

The model framework only accounts for limited substitution options and largely disregards feedback mechanisms between internal resources and market-purchased inputs. This explains the large trade-offs between household welfare and sustainable resource management that arise in the consumption smoothing simulation and for the landless households in the price band simulation. Whereas in most of the model simulations clear complementarities between welfare and sustainability are registered, resource constraints proved to be a critical bottleneck for enabling farmers to improve natural resource management practices when their food security is at stake. Further research on the specification of different livelihood strategies is conducted (in The Philippines) to understand the role of alternative strategies for balancing sustainable production and food security. Specific attention is paid to the role of remittances (from migration and non-farm employment) as collateral for borrowing and the potential spill-over effects between engagement in market exchange and investments in improved resource management practices.

Outlook

Development options for sustainable livelihoods in less-favoured areas can be identified for typical settings that reflect the natural, market and institutional constraints faced by different types of rural households. We used a stylized bio-economic model approach to identify the role of tenure regimes, savings for consumption smoothing, engagement in off-farm employment and the reduction of price bands as critical instruments for influencing farm production, household welfare and sustainability of resource use.

The results of the scooping study indicate that available options for pro-poor pro-environment policies in LFAs are rather restricted. Tenure reforms generate positive welfare effects for landless and small farmers, but only marginally reduce the pressure on marginal land. Furthermore, negative impacts for households with large land endowments create a concern for the implementation of a tenure reform policy. Improving saving capacities of poor farmers leads to an overall decline in welfare due to investment constraints that inhibit land use intensification. On the other hand, engagement in off-farm employment seems to offer prospects for addressing the resource constraints, enabling poor farmers to diversify risk while reducing the pressure on marginal land. Finally, public infrastructure investments aiming at reducing transaction costs is the only scenario that increases welfare for all households. Although this does have positive resource use implications at the village level, some households may intensify in a less sustainable way if credit constraints are not tackled simultaneously.

Further research on feasible strategies for overcoming poverty and resource degradation in LFAs needs to address critical constraints faced by farmers and villages in particular settings. Simulation approaches can be used to identify the available margins for adjusting land use and resource management by different types of farm households, and to understand the opportunities and constraints for initiating a process of sustainable intensification. Local case studies are helpful for further assessment of the feasibility of the identified development options and the viability of the required policy instruments.

Loose coupling of human and natural systems approaches can be a useful framework for understanding the global nature of the interactions between resource dynamics and farm household livelihood strategies. Insight into the linkages of coupled human-biophysical systems tends to be critical for identifying the opportunities for enhancing stability, reducing vulnerability or stimulating adaptation in rural livelihoods. Further understanding of the non-linear interactions and complex system-level behaviour asks for detailed field research on the interfaces between relevant biophysical and social processes (Bruce *et al.*, 2004).

Research regarding development pathways for LFAs could rely on such a generic modelling framework but needs to be complemented by more detailed field studies regarding the interactions between agro-ecological and socio-economic constraints. Particular attention will be paid to issues of temporal variation and feedback mechanisms that can be included into a multi-period modelling framework to identify possible synergies or trade-offs between income and resource use objectives (Kruseman, 2005). Moreover, the sequence of feasible policy incentives still deserves major attention in order to identify the most appropriate timing of interventions for a particular setting. Multi-agency simulation tools might be used to address in more detail the strategic interactions among different stakeholders

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Appendix 1

Model description

In the micro-macro model, representative households take decisions that maximize their utility. Decisions of one household may affect other households by changing demand or supply and thus prices of locally traded commodities. So when solving the model we need to maximize the utility of each household, while accounting for the interactions between households. Figure 1.1 sketches the structure of the model.

In order to find a model solution in which all households maximize their own utility we write the model in dual form, i.e., as a system of equations derived from the first-order conditions of household utility maximization. This is a common approach used in general equilibrium models. Instead of having an explicit maximization of utility the model thus consists of a set of consumption expenditure, input demand and output supply functions. Combined with commodity balances, requiring that total household demand for a good cannot exceed total household supply of a good, these equations describe behaviour consistent with utility maximization.

Household decisions are then driven by household prices, which are defined by a set of price equations. These equations determine the relevant price to be used in decision-making. For example, depending on whether a good is sold outside the local community (fixed price), inside the community (endogenous local price) or consumed in the household (endogenous household-specific price) a different price is relevant for decision-making.

We thus have for each household a set of equations determining its behaviour. We then solve this system of equations simultaneously to determine a solution in which each household maximizes its own utility while accounting for the interactions among households (i.e., the local market needs to be balanced as well).

A disadvantage of using a dual form as we use for our model is the loss of technical details important for sustainability assessment. In the macro-micro model this

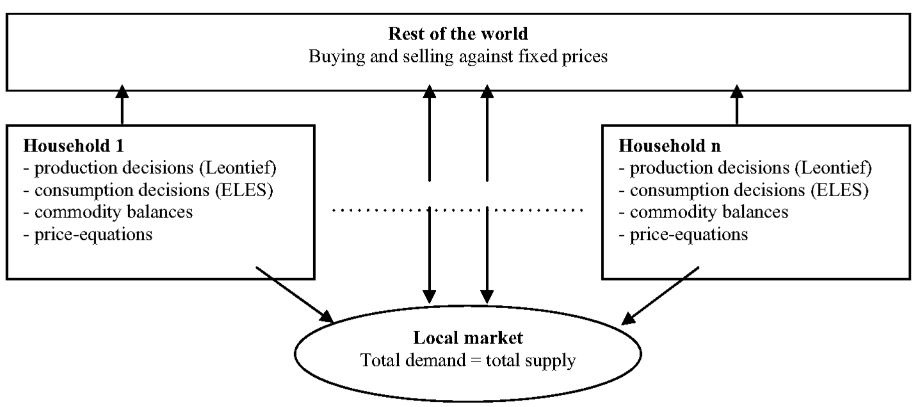

Figure 1.1. Outline of the model.

disadvantage is overcome by including Leontief technologies, as in bio-economic household optimization models. This allows us to include a set of Leontief technologies, as in bio-economic household models, while employing the general equilibrium structure to capture interactions among households.

Mathematical model description

The outline of the model sketched above translates to the following mathematical model description.

Consumption decisions

To account for savings in an a-temporal model we use an extended linear expenditure system (ELES) derived from intertemporal maximization of a Stone-Geary utility function. By treating savings as a normal, good, and proper choice of parameters, we arrive at an ELES in an a-temporal model (Howe, 1975). This yields the following sets of expenditure functions:

$$p_{hj}\, q^{c}_{hj} = p_{hj}\gamma_{hj} + \eta_{hj}(w_h - \sum_{j \in C} p_{hj}\gamma_{hj}), \qquad \forall\ h \in H,\ j \in C \qquad (1)$$

$$s_h = \rho_h(w_h - \sum_{j \in C} p_{hj}\gamma_{hj}), \qquad \forall\ h \in H \qquad (2)$$

with

$$\sum_{j \in C} \eta_{hj} + \rho_h = 1, \qquad \forall\ h \in H \qquad (3)$$

$$\rho_h = 1 - \frac{\delta_h}{r_h}\,,\ r_h > \delta_h, \qquad \forall\ h \in H \qquad (4)$$

where p_{hj} are household shadow prices, q^{c}_{hj} is household consumption, γ_{hj} are subsistence consumption quantities, η_{hj} are the marginal budget shares, w_h is household full income (i.e., the total income of the household, accounting for the consumption of farm-produced goods and leisure, measured as the value of household endowments, land and labour in the stylized model), s_h are household savings, ρ_h is the household propensity to save, δ_h is the discount rate, and r_h the return to capital. Variables and parameters are defined for each household of set H, while consumed commodities are part of set C of consumed goods.

As defined by Equation 3, expenditures on consumption and savings exhaust income after accounting payments for subsistence consumption. Furthermore, there are no subsistence expenditures on savings. By choosing household propensity to save according to Equation 4, the expenditure functions are consistent with intertemporal maximization. Consumption is restricted by household full income, defined as the value of household endowments plus additional cash income obtained by the household.

Production decisions

Household production decisions are based on Leontief production functions yielding the following set of equations:

$$q^{i}_{hj} = \sum_{a \in A} \sum_{t \in T} \alpha^{i}_{hatj} LA_{hat}, \qquad \forall\ h \in H,\ j \in I \qquad (5)$$

$$q^{o}_{hj} = \sum_{a \in A} \sum_{t \in T} \beta^{o}_{hatj} LA_{hat}, \qquad \forall\ h \in H,\ j \in O \qquad (6)$$

$$\sum_{j \in I} p_{hj} \alpha^{i}_{hatj} \geq \sum_{j \in O} p_{hj} \beta^{o}_{hatj} \perp LA_{hat} \geq 0\ , \qquad \forall\ h \in H,\ a \in A,\ t \in T \qquad (7)$$

where $q^{i}_{\eta j}$ are the total inputs used by the household, q^{o}_{hj} total produced output, α^{i}_{hatj} Leontief input coefficients, β^{o}_{hatj} Leontief output coefficients, and LA_{hat} the Leontief activity level. In addition we have set I of inputs, O of outputs, A of activities and T of technologies. Note that the specification of production by Equation 6 allows for multiple outputs by activity. The complementarity constraint Equation 7, derived from the first-order condition of Leontief technologies, determines which technologies are used. It specifies that if a technology is used, the value of output should equal the input costs. If input costs exceed the value of output the technology is not used.

Commodity balances

Household decisions are constrained by commodity balances, specifying that the use of commodities (from consumption, inputs in production or sale) cannot exceed the availability of commodities (from production, endowments and purchases):

$$q^{c}_{hj} + \sum_{a \in A} q^{i}_{haj} + q^{s}_{hj} + q^{ht}_{hj} \leq + q^{o}_{hj} + \bar{q}^{\omega}_{hj} + q^{p}_{hj}, \qquad \forall\ h \in H,\ j \in J \qquad (8)$$

where, in addition to the variables defined before, q^{ht}_{hj} is the net marketed surplus of household tradables, q^{s}_{hj} is the amount sold of a price-band commodity, $\bar{q}^{\omega}_{hj}$ is the fixed household factor endowment, and q^{p}_{hj} is the amount purchased of a price-band commodity. Commodity balances are specified for all commodities, although the balance will only be constraining decisions of imperfectly tradable commodities. Commodities that can be sold and purchased will be bound by the cash constraint, which is implicit in the model.

Price equations

The market position of households is determined by a set of price equations introducing price bands in the model. More specifically, there are three types of commodities in the model. Household *nontradables* cannot be traded, their household shadow price (p_{hj}) is determined by household supply and demand as determined in Equation 8. Household tradables (set HT) do not have a price band and have a price exogenous to the household,

$$p_{hj} = \tilde{p}_j, \qquad \forall\ h \in H,\ j \in HT \qquad (9)$$

We indicate the exogenous price by a tilde (~) since in the micro-macro model the prices of household tradables are determined at local markets,

$$\sum_{h \in H} q_{hj}^{ht} \leq 0, \qquad \forall\ j \in HT \qquad (10)$$

So we require total supply of commodities to the local market to exceed (prices are then zero) or equal demand.

For commodities traded outside the local market, we assumed (household-specific) price-bands to apply. The relevant decision-making price thus depends on the household's market position, which is introduced through complementarity constraints:

$$\bar{p}_j + \tau_{hj}^{p} \geq p_{hj} \perp q_j^{p} \geq 0, \qquad \forall\ h \in H,\ j \in P \qquad (11)$$

$$p_{hj} \geq \bar{p}_j - \tau_{hj}^{s} \perp q_j^{s} \geq 0, \qquad \forall\ j \in S \qquad (12)$$

where $\bar{p}_j$ is the exogenous price and τ_{hj} is the price-band for either buying (p) or selling (s).

Appendix 2

Base-Level parameters

The data presented in Table 2.1 are the parameters for consumption behaviour for a reference household with an income normalized to 100.

The parameters for the Leontief technologies are derived from Constant Elasticity of Substitution (CES) production functions. Table 2.2 summarizes the base level inputs by agricultural activity to provide an indication of the differences across activities in terms of input use.

In addition to these base level technologies, for all activities alternative technologies are defined. These are derived by increasing and decreasing labour with 5, 10, 15 or 20% and computing – with the use of a CES function – the required change in other inputs (land and external inputs) to maintain production. To allow cash constraint households to cultivate crops, for the staples and high-value crops a technology without use of external inputs is specified, requiring more labour while yielding 50% less output. To allow households with a limited endowment of pasture to engage in livestock, a more labour intensive livestock technology using marginal land instead of pastures is defined as well.

Table 2.1. Parameters consumption decisions.

	Income elasticity	Expenditure share	Committed quantities	Marginal budge share
Staple crop	0.62	0.25	16.79	0.15
High-value crop	0.71	0.13	7.81	0.09
Livestock	0.96	0.13	6.12	0.12
Other food	0.86	0.10	5.46	0.09
Manufactured goods	1.85	0.15	0.32	0.28
Leisure	0.90	0.20	10.46	0.18
Savings	1.89	0.05	0.00	0.09

Table 2.2. Base inputs production activities.

	Labour	Land [1]	Pasture	External inputs
Single crop	0.6	0.3		0.1
High-value crop	0.7	0.2		0.1
Non-food crop	0.5	0.3		0.2
Livestock	0.3		0.7	
Local business activities	0.6			0.4
Off-farm employment	1.0			

[1] All crops can be grown on cropland and marginal land, with the same inputs. However, on marginal lands yields are 20% lower.