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Cornell University, Ithaca, New York 14853-7801 USA

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Stein Holden
Christopher B. Barrett
Fitsum Hagos

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Stein Holden[1], Christopher B. Barrett[2] and Fitsum Hagos[1,3]

[1]Department of Economics and Resource Management, Agricultural University of Norway, P.O.Box 5033, 1432 ÅS, Norway.

[2]Department of Applied Economics and Management, Cornell University, 315 Warren Hall, Ithaca, NY 14853-7801 USA.

[3] Mekelle University, Mekelle, Tigray, Ethiopia.

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Abstract

Food-for-work (FFW) programs are commonly used both for short-term relief and long-term development purposes. In this paper we assess the potential of FFW programs to reduce poverty and promote sustainable land use in the longer run. There is a danger that such programs distort labor allocation or crowd out private investments and therefore have negative side effects. How important are such effects, when are these effects small and large, and when and how can they be reduced? How do technology and market characteristic and the design of FFW programs affect the long-run impact of FFW interventions? When, where and how can FFW programs more efficiently reduce poverty and promote more sustainable land management? Could FFW programs even be used to crowd in private investments? The paper attempts to provide answers to these questions, drawing on empirical evidence and an applied bio-economic farm household model for a less-favoured area in northern Ethiopia.

Summary

Recent research on food-for-work (FFW) programs has focused on the short-term impacts in terms of poverty targeting efficacy and protection against shocks. While these issues are important, there has been a tendency to neglect the more long-term effects of FFW in terms of poverty reduction, growth enhancement and natural

resource conservation. Most hunger in the world is due to chronic deprivation and vulnerability, not short-term shocks. Furthermore, many FFW programs have explicit long-term objectives as primary or equally important objectives. On this basis this paper assesses the potential of FFW to contribute to poverty reduction and natural resource conservation in the longer run. We do this through analysis of survey evidence from northern Ethiopia that we use to motivate a simple theoretical model, a less general and more detailed version of which we then implement through an applied bio-economic model calibrated to northern Ethiopia. The analysis explores how FFW project outcomes may depend on FFW project design, market and technology characteristics. We show that FFW programs may crowd out or crowd in private investments and highlight factors that may pull in different directions.

Our empirical evidence from northern Ethiopia shows that time constraints and food supplied through FFW may crowd out other activities and own food production. However, we also found that FFW projects could crowd in private investment in soil and water conservation by providing technical support, mobilizing local labor, coordinating activities across farms, resolving resource conflicts and possibly providing insurance and reducing personal discount rates.

We then illustrate the possible crowding out effects through a simple static household model with imperfect markets. The dynamic extension of the model illustrates the possible crowding in effects through investment-stock effects related to the natural resources and human resources of households.

Finally, we illustrate the inherent ambiguity of FFW projects' effects on long-term productivity and natural resource conservation through a bio-economic household model applied to an area in northern Ethiopia. This dynamic, non-linear, non-separable household model simultaneously integrates economic optimization in production and consumption with intertemporal environmental feedbacks. Different scenarios are compared. First, FFW employment directed outside agriculture can be compared against FFW applied within agriculture in form of investment in land conservation. We show how assumptions about access to alternative off-farm employment (i.e., the opportunity cost of farmers' time) and the short-term impacts of conservation technologies on farm productivity affect outcomes of FFW interventions. The simulations show that FFW targeted outside agriculture may reduce incentives for agricultural production and land conservation and therefore have negative crowding out effects. However, if FFW is targeted at investment in land conservation, FFW may enhance agricultural production in the longer run and lead to more sustainable production. The conservation effects of FFW may be higher when the private incentives for conservation are lower.

We conclude that FFW projects have the potential of contributing to long-term development in economies characterized by imperfect markets but poor design and implementation can easily lead to the opposite result. It is a skill and knowledge-demanding task to design and implement efficient FFW program and a lot of room for improvement of existing programs.

I. Introduction

Food-for-work (FFW) programs are commonly used both for short-term relief and long-term development purposes. In the latter capacity, they are increasingly used for natural resources management projects. In this paper we explore the question of FFW programs' potential to reduce poverty and promote sustainable land use in the longer run through induced changes in investment patterns.

FFW programs commonly aim to produce or maintain potentially valuable public goods necessary to stimulate productivity and thus income growth. Among the most common projects are road building, reforestation, and the installation of soil conservation measures or irrigation. In the abstract, public goods such as these are unambiguously good. There is a danger, however, that such programs could discourage private soil and water conservation and crowd out private investment. How important are such effects, when are these effects small or large, and when and how can they be reduced? How do market characteristics and the timing and design of FFW programs affect long-term productivity impacts of FFW programs? When, where and how can FFW programs more efficiently reduce poverty and promote more sustainable land management? The paper aims to answer these questions.

Much recent empirical research has focused on the shorter-term issue of whether FFW and related workfare programs efficiently target the poor (Dev 1995, von Braun 1995, Webb 1995, Subbarao 1997, Clay et al. 1999, Devereux 1999, Jayne et al. 1999, Ravallion 1999, Teklu and Asefa 1999, Atwood et al. 2000, Gebremedhin and Swinton 2000, Haddad and Adato 2001, Jalan and Ravallion 2001). Much less research has been focused on the longer-term effects of FFW. Yet the large share of hunger worldwide arises due to chronic deprivation and vulnerability, not short-term shocks (Speth, 1993, Barrett, 2002). Also, many FFW programs around the world have explicit long-term objectives that are at least as important to the program managers and participants as short-term transfer objectives. For example, most of the FFW programs in Ethiopia have long-term development goals and are formally distinguished from the disaster relief FFW programs[1] (Aas and Mellemstrand, 2002). In a case study in Tigray, Aas and Mellemstrand (2002) found that the FFW recipients considered the long-term benefits of FFW as more important than the short-term benefits of food provision. It is therefore appropriate to evaluate these programs based on their long-term goals and not only on the basis of short-term targeting efficacy.

FFW programs may produce valuable public goods. For example, von Braun et al. (1999) report multiplier effects of a FFW-built road in the Ethiopian lowlands. Public provision of public goods related to the natural environment may be socially desirable because private investment in soil and water conservation and tree planting may be well below socially optimal levels due to poverty and market imperfections (Holden et al., 1998, Holden and Shiferaw, 2002, Holden and Yohannes, 2002, Pender and Kerr, 1998), tenure insecurity (Gebremedhin and Swinton, 2000, Holden et al., 2003), or lack of technical knowledge and coordination problems across farms (Hagos and Holden, 2002). There is, however, also a danger that FFW programs crowd out private investments (Gebremedhin and Swinton, 2000).

[1] Actually, only programs with long-term development objective are called FFW programs in Ethiopia, while programs with short-term relief as primary objective are called Employment Guarantee Scheme (EGS) programs.

We study the long-term effects of FFW programs on agricultural productivity, resource conditions and the incomes of poor households using multiple methods. First, in section II we discuss FFW programs in general and present some empirical evidence from northern Ethiopia on the use of FFW for long-term investments, especially soil and water conservation structures. Section III introduces a simple theoretical framework for understanding the analytically ambiguous effects of FFW programs on the sustainability of land use patterns and the incomes of program participants. We first present the basic intuition in a static framework to illustrate the selection, crowding out and targeting issues, before generalizing it to a dynamic model to illustrate the possible insurance and crowding in effects of FFW. Section IV then uses a less general, applied, dynamic bio-economic farm household model applied to a less-favoured area in northern Ethiopia to investigate via numerical simulation how household welfare and land use patterns vary with changes in environmental and FFW program design parameters. Section V discusses our findings and fleshes them out a bit with further empirical evidence. Section VI concludes.

II. Food-for-work programs

a. General background on food-for-work

FFW has become increasingly popular over the past decade, especially in Sub-Saharan Africa (Devereux 1999, von Braun et al. 1999). FFW programs typically aim (i) to provide participants with at least the minimum essential quantity of food necessary to maintain good nutrition, (ii) to require work in exchange for this benefit, (iii) to reduce or decentralize both the targeting of beneficiaries and the prioritisation and management of public works projects, and (iv) to harness the few resources available, whatever the form in which they are available (e.g., food), to try to advance long-term development objectives in food-deficit areas.

The long-term development objectives of FFW programs can be realized through either of three distinct channels. First, well-run FFW programs provide insurance against transitory income shocks, effectively guarantee of a minimum income to all who are willing to work. This puts a floor beneath labor productivity and income, keeping people from suffering excessively in the wake of temporary shocks and from employing labor excessively in activities that may have long-run costs (e.g., soil nutrient mining, over harvesting wildlife, excessive forest clearing, prostitution, etc.).[2] The insurance function of food-based safety nets can both preserve valuable human capital in the face of income shocks and, by reducing downside risk exposure, encourage greater asset accumulation, adoption of improved technologies and natural resources management practices and other higher risk-higher return activities.

Second, FFW represents a transfer and, as such, can relieve seasonal liquidity constraints that might limit farmer purchase of valuable inputs and investment in productivity enhancements, such as soil and water conservation structures. There is some evidence from Kenya (Bezuneh et al., 1988, Barrett et al., 2001) that well-targeted and well-timed FFW initiatives have proved successful in relaxing poor farmers' short-term liquidity constraints, thereby enabling them to increase their medium-to-long-run productivity through purchases of improved seeds and inorganic fertilizer, reduced distress sales of valuable livestock and machinery, and keeping children in school.

[2] See Barrett and Arcese (1998) or Barrett (1999) for examples of the connection between stochastic labor productivity and environmental degradation and the prospective role for labor-based safety nets.

Third, FFW programs can create new, valuable public goods, such as roads, irrigation and soil and water conservation structures to reduce erosion and improve agricultural productivity. These public goods can increase future productivity, especially if their provision helps induce private capital accumulation as well because the returns to private investment depend in part on complementary investments by others, as is commonly the case in natural resources management (e.g., weed control, pest control, erosion control through terracing, etc.) due to coordination problems (Barrett, 2003, Hogset 2003).

Of course, because FFW is not a lump sum transfer, it necessarily has distortionary effects as well, especially with respect to labor allocation. If the public goods created by FFW programs are of low quality or prove unsustainable and FFW diverts resources away from productive private activities, it can undermine long-term productivity and resource sustainability. It remains an open question how these effects net out and the conditions under which one might reasonably expect FFW programs to prove stimulative or counterproductive. While much of the research on FFW has focused on the short-term effects associated with targeting efficacy, in this paper we are more interested in the longer-term effects on the natural resource base and farmer productivity and poverty.

b. Evidence from northern Ethiopia

Ethiopia is one of the poorest countries in the world and the Tigray region of northern Ethiopia is one of Ethiopia's poorest. Erratic rainfall, land degradation and high population density cause the livelihoods of millions of people who depend heavily on semi-subsistence agricultural production to be threatened both in the short and the longer run. Policy failures and wars have further contributed to a neo-Malthusian development path of deepening poverty and natural resource degradation, although there have been signs of more positive development over the last ten years. This may be due to a more market friendly approach combined with strong government support and local collective action to rehabilitate local livelihoods. Still, food security is threatened by frequent droughts and the majority of the population is net buyers of food who regularly receive food aid. Most of this food aid has been distributed through FFW programs. If FFW can not only help prevent under nutrition but also help reduce natural resources degradation associated with soil erosion and nutrient depletion in hilly, rain fed agriculture, it could have quite a salutary effect on poor Tigrayan farmers.

We motivate the theoretical and simulation work of subsequent sections by illustrating a few basic patterns from survey data covering 400 households in 16 communities in the highlands of Tigray. The sub-sample of 16 communities was strategically chosen to include four communities from each of the four zones in Tigray, to have eight communities with high population density and eight with low population density, to have eight with good market access and eight with poor market access, and to include three communities with irrigation projects. The households were surveyed in both 1998 and 2001. We have complete data for both years for 323 households.

The government of Ethiopia has a policy of committing 80 percent of food aid resources to FFW programs, although in practice this varies considerably, particularly in emergencies and in pastoral areas (Sandford and Habtu, 2000). FFW has been especially widespread in northern Ethiopia as the government has tried to improve food security and promote sustainable development in a chronically poor and food insecure region. Fifty-seven percent of our sample households participated in FFW projects, supplying an average of 45 labor man-days in 2000, with greater participation in remote areas with poor market access.

Crowding out or crowding in effects of FFW?

In the first round survey in 1998, 21% of the households stated that FFW participation gave them less time to look after their farm and animals, while only one percent stated that it gave them more time to look after their farm and animals (Hagos and Holden, 1998). Furthermore, 43% stated that FFW reduced their need to produce own food, while only four percent stated that it made them able to invest more on their own farms. This suggests that FFW may indeed have some crowding-out effects on farm labor and production. On the other hand, the insurance function played by FFW may reduce the subjective discount rates and increase the planning horizon of poor people (Holden et al., 1998; Holden and Shiferaw, 2002). Lower discount rates and longer planning horizons increase the attractiveness of investment relative to current consumption and would thereby be expected to have the opposite, crowding-in effect on private on-farm investment, including in soil conservation.

Table 1 enumerates the various FFW activities in which sample households participated. As can be seen, much FFW activity in Tigray has focused on soil and water conservation. Initially, much of these activities were carried out on communal land. In the second half of the 1990s these activities also expanded into the private land holdings. These investments were also complemented by mass mobilization of labor at community level. Mass mobilization has been an annual activity in Tigray for many years. Each able-bodied adult person has to contribute 20 days of work to the community without any direct payment. This may be seen as a publicly organized collective action or a uniform labor tax that is invested within the local community, which also decides on where to allocate the mobilized labor. Table 2 presents the types of activities households participated in through mass mobilization in 1997.

The survey also asked households what assistance they considered important in order to be able to reduce land degradation in their area. Their responses are summarized in Table 3. Respondents universally considered technical assistance most important, although many emphasized the importance of labor mobilization and conflict resolution as well. There is clearly a need to coordinate conservation activities across farms and considerable technical skills are required to design and fit the alternative conservation technologies into the landscape. Given the spatial externalities associated with soil and water conservation structures among contiguous farms, there may be natural disincentives to undertake private, uncoordinated investment in land improvements that will benefit one's neighbors or that may prove unproductive in the absence of complementary investments by neighbors upslope. This adds an additional rationale for public intervention to promote land conservation on private land. FFW may in this connection also be beneficial as a complementary instrument to mass mobilization to increase investment on privately operated land. The result may be crowding in rather than crowding out of private investment due to the demonstration, coordination, labor mobilization, insurance and conflict resolution effects.

How are public and private investments distributed across farm plots? Table 4 presents the distribution of public and private investment in soil bunds and stone terraces at farm plot level. Roughly half of the plots with privately-built stone terraces also had public conservation investment, while only about one-quarter of the plots on which there had been public conservation investments had privately-built stone terraces. These patterns were roughly similar for soil bunds. These data provide an uncommon opportunity to analyze the determinants of private investment in conservation at plot level, in particular the effect of public conservation investments through FFW and other labor mobilization schemes on private soil conservation investments (Hagos and Holden, 2003).

Hagos and Holden (2003) found that public investment at plot level was positively correlated with private investment in conservation through both soil bunds and stone terraces. Such positive correlation was found both for the probability of private plot level conservation and the intensity of plot level private conservation investment. In that analysis, we controlled for a large number of soils and plot characteristics, household characteristics, village and market characteristics. This seems strong evidence that public conservation investments can indeed crowd in private investment in soil and water conservation. This beneficial effect seems to have multiple sources – the need for technical support (demonstration effect), coordination across farms, labor mobilization, insurance and conflict resolution – although the data do not permit us to distinguish between these cleanly. The combination of FFW and mass mobilization may reduce the labor depreciation cost of mass mobilization and thus facilitate further private conservation efforts. This is also in line with the argument that FFW may provide insurance and reduce the severity of cash constraints and thus private discount rates. We now formalize some of these basic ideas about crowding out and crowding in effects of FFW in some simple theoretical models.

III. Theoretical Framework

With this empirical backdrop firmly in mind, we now develop a simple model of household labor allocation. We start with a static version of the model, which lets us focus tightly on the effects of FFW participation on household labor allocation to farming activities. In the second subsection, we then generalize the framework to explore the dynamics of household welfare, land use patterns and investment in soil conservation. In section IV, we then present findings from a bioeconomic simulation model that simplifies the general model developed in this section and places it in the specific northern Ethiopia context we have just described.

a. *A simple, static model*

We begin with a simple, static model of household choice in an environment of missing markets for labor and land. While we are ultimately concerned with the long-term effects of FFW on land use patterns, this parsimonious introduction underscores the importance of initial resource endowments when factor markets work imperfectly or not at all. Assume that the household maximizes utility, where utility is a function of consumption (*c*) and leisure (*Le*).

$$U = U(c, Le) = U(p_q q(L_a, \overline{A}) + w_{FFW} L_{FFW}, T - L_a - L_{FFW}) \quad (1)$$

where p_q is the price of output produced (the consumption good is taken as the numéraire), $q(\bullet)$ is a production function that is concave in each argument, with the marginal returns to each input increasing in the other inputs, L_a is labor input in farm production, $\overline{A}$ is the land endowment[3], w_{FFW} is the FFW wage rate, L_{FFW} is the amount of FFW labor supplied by the household, and *T* is the total time endowment. Because the model is static and the utility function satisfies the usual local non-satiation assumption, the household consumes all its cash income (*y*). This model has no factor markets for land, only a market for FFW labor and a market for farm output. The two decision variables in the model are labor in agricultural production and labor in FFW. The first order conditions imply

$$w_{FFW} \leq w^{*} = \frac{\partial U / \partial Le}{\partial U / \partial c} = p_q \frac{\partial q}{\partial L_a} \qquad (2)$$

where w^* is the household's shadow wage rate, the marginal revenue product of labor in agriculture on the household's farm. The first order condition provides the selection mechanism that underpins household choice over whether or not it participates in the FFW program. It participates only if the returns to farm work are as low as the FFW wage, in which case it will allocate labor so as to equalize the marginal returns to labor in agriculture and FFW (if access to FFW is unconstrained). If the household chooses to participate in the FFW program, it necessarily diverts labor away from on-farm activities. Since output is monotonically increasing in L_a, average productivity per hectare cultivated or per person necessarily falls.

b. *A dynamic extension*

We now generalize the simple model above to account for the dynamics of investment in soil conservation structures. This requires four key modifications to the static model of the previous subsection. First, in the dynamic model the household no longer consumes all its income today so long as there is some prospect of being alive

[3] One can equally think of $\overline{A}$ as the stock of quasi-fixed inputs, including not only land but also livestock and other productive farm assets.

tomorrow. Instead, the household has to allocate current income between consumption and investment so as to equalize its marginal utility of consumption across periods. Second, while in the static model, households will only devote labor to activities that generate current income, in a dynamic model; they might invest labor in activities that generate income only with a lag. We therefore now break household agricultural labor into two distinct activities: field labor that generates income in the current period and conservation labor spent improving the land so as to increase future productivity and income.[4] We model soil conservation investments this way because natural resources investments in African agriculture tend to be very labor-intensive (Barrett et al., 2002). This leads directly to the third basic difference from the static model: effective land quantity is now a state variable. The initial stock of land evolves in response to soil and water conservation investments and natural degradation due to erosion and nutrient depletion. Farmers understand this and make labor allocation decisions accordingly. Fourth, and similarly, the total stock of labor available to the household is now dynamically endogenous as well. Future labor availability depends in part on current consumption of food (to maintain health and physical vigor) and of leisure (on current energy expenditure in work). Households know that they cannot starve themselves today and devote all of their time to work – without any leisure/recovery time – else the short-term income and savings gains they enjoy will be overwhelmed by loss of future human capital due to illness, fatigue or even death.

[4] One could equally understand land dynamics as depending on labor allocation through labor-intensive land clearing at the extensive margin (Reardon and Barrett, 2001). In the Ethiopian context on which we focus in the empirical sections of this paper, however, soil and water conservation is the more germane link, so we focus on that interpretation for the remainder of the paper.

Assume the household's utility is inter-temporally separable. Then the household's infinite period dynamic optimization problem can be represented by the following Bellman's equation, in which β represents the household's discount rate, L_c is the amount of labor allocated to constructing or maintaining soil conservation structures, δ^A and δ^T are endogenous depreciation rates for land and labor stocks, respectively, z is the stock of productive public goods, and I is net investment in conservation units:

$$\underset{c_t, Le_t, L_{at}, L_{ct}, L_{FFWt}}{Max} \quad V(A_t, T_t) \equiv U(c_t, Le_t) + \beta V(A_{t+1}, T_{t+1})$$

$$= U(p_{qt} q(L_{at}, A_t, z_t) + w_{FFW} L_{FFWt}, T_t - L_{at} - L_{ct} - L_{FFWt}) + \beta V(A_{t+1}, T_{t+1}) \tag{3}$$

$$\begin{aligned} s.t. A_{t+1} &= \delta^A(q_t, L_{ct}, z_t) A_t + I(L_{ct}, z_t) \\ T_{t+1} &= \delta^T(c_t, Le_t) T_t \end{aligned}$$

We include the public good, *z,* because the typical justification for FFW programs is that they couple a short-term safety net for vulnerable subpopulations with investment in valuable public goods – roads, reforestation, irrigation, soil and water conservation structures – that increase future productivity. The short-term safety net provides an income floor to insure against insufficient current consumption, thereby guarding against loss of household labor due to illness or injury associated with under-nutrition, through the δ^T human capital depreciation function.[5] As modeled here, the public good may affect the rate of depreciation of land (e.g., through reforestation projects

[5] In a more general specification, one might allow for the sale of quasi-fixed assets. FFW could then reduce disinvestment in valuable productive assets, as commonly occurs in distress sales of land or livestock. Since we treat land and livestock as non-tradable, we omit the distress sale mitigation effect from the present model. Similarly, FFW could permit continued investment in other key assets, such as children's education. Given low school enrollment rates in rural Ethiopia, we likewise omit the possibility of educational investments and thus of FFW stemming the withdrawal of children from school during times of stress. Finally, one could allow the discount rate, β, to be an endogenous function of current consumption (reflecting how survival probabilities vary with consumption levels), with the effect that FFW wage receipts limit households' discounting of future consumption, thereby encouraging greater investment in conservation structures. Although we omit them from the formal model in this section for reasons of parsimony, these phenomena nonetheless merit attention in empirical work.

that reduce erosion or feeder road construction projects that accelerate erosion[6]), the productivity of conservation labor in improving land quality (e.g., due to terracing or reforestation of public lands on hilltops that increases the productivity of private terracing down-slope), or direct agricultural productivity (e.g., through small-scale irrigation projects).[7]

The laws of motion for the state variables *A* and *T* each depend on endogenous depreciation rates. Land quality depreciates with increased harvests that extract more soil nutrients and with higher rates of erosion (part of the *z* vector), while land quality increases with time spent working on conservation structures and with public goods that stem erosion (e.g., reforestation or terracing). The stock of labor available to the household is increasing in energy consumption (*c*) and decreasing in energy expenditure (equivalently, increasing in leisure, *Le*). Given initial values A_0 and T_0 and exogenous public goods stock z_0, the household then solves the current value Hamiltonian associated with the above problem.

This specification reveals the inherent ambiguity of FFW programs' effect on land quality. If the household chooses to participate, FFW program participation will reduce time allocated to both on-farm labor and leisure. Because households rationally equalize the returns to field and conservation labor – the two forms of on-farm labor we consider – so as to equalize the marginal utility of current and future consumption, FFW participation will induce a reduction in labor allocated to soil and water conservation, *ceteris paribus*. This can reduce land quality and hurt future

[6] Ziegler and Giambelluca (1997) find in hilly, smallholder regions of northern Thailand that unpaved roads are, by far, the primary source of water runoff and erosion, having far greater adverse effects on soil loss and siltation of downstream irrigation than forest clearing due to shifting cultivation.
[7] One might also want to permit prices to be a function of *z* so as to capture the effect of road building or maintenance projects on marketing transactions costs. We leave this extension for future work.

productivity. Similarly, if the reduction in leisure due to FFW participation outweighs the increase in current consumption – as has been shown to happen in some FFW programs, where women especially have been known to increase energy expenditure by more than the marginal increase in energy intake they enjoy (Barrett et al., forthcoming) – then there may be some degradation of household labor capacity, and thus of future earnings potential.[8]

These possible adverse effects may be dampened or even dwarfed by the potentially salutary effects of FFW on land quality through avoidance of lost labor time due to under-nutrition, through reduced pressure on the land due to reduced current cultivation (i.e., the crowding out of current field labor can reduce rates of soil nutrient harvest), and via investment in public goods, z, especially if the marginal returns to investment in soil conservation, $\partial I/\partial L_c$, is increasing in z due to complementarities between public and private capital investment. Whether the negative or positive land quality effects of FFW dominate will depend on local biophysical and economic environmental conditions and on the design of the FFW program, as Section IV illustrates through simulation modeling techniques.

IV. Simulations with a dynamic bio-economic model

The bio-economic model[9] presented here is a dynamic, nonseparable household model that simultaneously integrates economic optimization in production and consumption with inter-temporal environmental feedbacks, allowing for nonlinearities in constraints as well as in the objective function. The model also incorporates risk

[8] One sometimes hears claims that FFW programs also create dependency or retard innovative behaviour. We know of no strong empirical evidence of such effects, however, and they fall outside the scope of the present modelling effort.
[9] A brief technical representation of the model is included in an appendix.

averse behavior through a constant partial relative risk aversion utility function, production risk due to drought[10], and downside risk aversion to taking credit for fertilizer. Drought also affects prices for crops and livestock and price expectations and these have follow-on effects on household production and welfare. The model has been calibrated and aggregated to resemble observed patterns in a specific area of northern Ethiopian. However, household interactions through their participation in imperfect factor and output markets are characteristic for large parts of northern Ethiopia. We refer interested readers to Holden and Shiferaw (in press), Holden et al., (2003), and Holden et al. (forthcoming) for more details and applications of the bio-economic model employed in this section.

The model endogenizes land degradation due to soil erosion and nutrient depletion. The availability of biophysical data from conservation experiments in the study area allows us to estimate erosion rates as well as crop productivity responses on different soils. The model also integrates crop and livestock interactions. Crop choice, building or removal of conservation structures on different types of land, fertilizer use, and manure use are endogenous decisions that affect the rate of land degradation. These decisions affect soil erosion and nutrient depletion rates that, once again, determine crop productivity in later years.

We want to assess the impact of new FFW programs in northern Ethiopia that aim to enhance food security through provision of seasonal employment at a low wage rate paid in kind, in the form of food. In what follows, we study the impact of FFW under three distinct scenarios. In the first, scenario (a), FFW employment is directed outside

[10] The probability of drought in the model is assumed to be 0.1, see Holden and Shiferaw (in press) for more details on the impacts of drought.

agriculture. In the second, scenario (b), FFW employment is provided for conservation investment within agriculture. In the first two scenarios, we therefore distinguish between alternative sectoral allocations of FFW labor. We assume that access to off-farm employment is constrained (i.e., households do not face infinitely elastic labor demand) and that conservation investment does not reduce initial yields. Scenario (c) is like scenario (b), but with unconstrained access to off-farm employment and with conservation investment reducing initial yields[11]. Both these changes reduce incentives for farm production and conservation investment). In cases (b) and (c) we assume that the investment is taking place on the FFW participant households' farms. In all cases the "wage rate" in FFW is 3 kg wheat per day of work, the standard rate used in FFW programs in Ethiopia.

One oft-heard criticism is that FFW will undermine participants' incentives to produce their own food and to take care of their own farms, partly because FFW activities compete for scarce time with households' private farming activities. FFW advocates counter that FFW provided outside the main agricultural season stems such competition, enabling FFW investments and income to be largely additional to the household's private earnings and investment patterns. However, FFW may still compete with households' own conservation activities, as these activities are typically carried out in the slack agricultural season. In the site for which we developed this model, Andit Tid in northern Ethiopia, there are two growing seasons. It is most relevant to provide FFW after the short rains, that is in the period March to May, during which time households indeed undertake most of their soil and water conservation investments through labor intensive work on structures on-farm.

[11] There is location-specific variation in terms of access to non-farm income and the short-term effects of conservation technologies on yields in northern Ethiopia (Holden and Shiferaw, in press; Holden et al., forthcoming)

In our first simulation (scenario (a)), we study the impact of FFW not used for conservation, when households have constrained access to the labor market[12], and conservation technologies do not reduce initial yields[13]. We see from the eight graphs that comprise Figure 1 that over the whole ten year horizon we simulate, FFW increases income per capita compared to the base case model in which households lack access to FFW employment. We also see that own food production is reduced in normal as well as in drought years for households with access to FFW. This occurs because households with access to FFW reduce farm labor use, including soil conservation labor. Reduced labor allocation to construction and maintenance of soil conservation structures means that a smaller proportion of the farm is conserved and total soil erosion increases among households with access to FFW. Scenario (a) thus demonstrates the clear costs of providing FFW in an environment and in a fashion in which it may reduce incentives for own food production and conservation, thereby undercutting future productivity and increasing the likelihood that participant households will need future assistance as well.

In scenario (b), we only change the allocation of FFW labor, now assuming it to be applied to conservation on participating households' farms, again under the twin assumptions of constrained labor market access and no initial yield reduction due to conservation investments. The results are presented in Figure 2. Household income per capita once again increases for FFW participant households. But because FFW labor no longer crowds out on-farm conservation labor, FFW stimulates increased

[12] This may imply a low opportunity cost of time outside the agricultural season.
[13] This implies that returns to conservation are fairly good. These two conditions imply that the private incentives for conservation are good. FFW, however, raises the opportunity cost of time during the period FFW is offered and this may crowd out private investment in conservation.

land conservation – as compared to scenario (a), where FFW leads to reduced land conservation – and thus leads to less soil erosion, although the long-term impact on household net food surplus is relatively modest.

In scenario (c), we alter two of the initial assumptions in order to study the impact of FFW used for on-farm conservation when households have unconstrained access to the labor market (i.e., they enjoy better non-farm employment opportunities than previously assumed and thus have a higher opportunity cost of time) and conservation technologies reduce initial yields, thereby dampening private incentives to conserve land. Figure 3 reports the results of the scenario (c) model simulations.

As always, household income per capita increases for households that choose to participate in the FFW program, because FFW represents an income transfer. However, the gains are less under scenario (c) than when access to the labor market was constrained because FFW no longer resolves a structural deficit in labor demand. FFW participation in an environment in which cash wage employment is available implies that the FFW payment (3 kg wheat per day) is higher than the cash wage prevailing on the local labor market. As a consequence, FFW substitutes for other off-farm work, causing a reallocation of labor within the economy.

On the other hand, FFW stimulates own food production and reduces food deficits in normal as well as drought years, and particularly so towards the end of the ten year period for which the models have been run. This arises largely because FFW is used for land conservation, which makes farm production more sustainable. Without FFW, households do not invest in conservation at all because conservation reduces initial yields and because they have alternative off-farm employment opportunities. This scenario illustrates how FFW can help poor households overcome borrowing constraints that restrict costly investment. The food provided by FFW enables households to reallocate labor from current on-farm production without forcing them to make an excessive sacrifice in terms of current consumption. Indeed, the corepoint of this paper is that these sorts of desirable crowding-in effects only emerge under particular combinations of FFW program design and the underlying biophysical and economic environment.

The effects of FFW on food production and conservation of land can differ greatly depending on how and for what activities FFW is used, on the characteristics of the local labor market, and on the impact of conservation technologies on short-term yields. In order to demonstrate this, we also run simulations with a reduced FFW wage rate. We found that households should choose to participate in FFW programs at wages as low as 1.1 kg wheat per day (down from the 3 kg/day baseline commonly used in Ethiopian FFW programs).[14] The level of soil conservation investment was not reduced significantly when the wage was reduced from 3 kg to 2 kg wheat. If the main objective of long-term oriented FFW programs is to promote land conservation and the budget for this is limited, it would seem possible to expand total land conservation by reducing the FFW wage. This may also improve program targeting as more wealthy households would be inclined to opt out of the FFW program at lower wage, thereby allowing limited funds to reach more poor households.

The land use effects of FFW projects have not been well studied. The simulation results reported in this section underscore that when FFW competes with labor used

[14] Barrett and Clay (2003) use survey-based willingness to participate data to elicit FFW labor supply curves in rural Ethiopia and similarly find a nontrivial population of households willing to participate at extremely low program wage rates.

for conservation, FFW may reduce incentives to conserve land, at least where such incentives exist without intervention. On the other hand, FFW may be used to stimulate conservation when there are insufficient incentives to conserve land, as in the case when initial yields fall with the construction of soil conservation structures. This illustrates that great care has to be taken in the design of such programs if they are to overcome private investment disincentive effects and not to crowd out private investment in soil conservation. Good knowledge about local farming systems, local market characteristics and prices, and the distribution of resources and welfare, are needed to avoid design failures. Lack of such knowledge by many past FFW program managers likely helps explain mixed past experience with such programs (Barrett et al., forthcoming).

V. Discussion

FFW projects have been implemented for short-term relief purposes as well as long-term development purposes in Ethiopia and other low-income countries. There may be tradeoffs between the short-term assistance and long-term investment objectives of FFW (Gebremedhin and Swinton, 2000). It may be that one can basically enjoy effective safety net effects that protect valuable human capital against irreversible damage due to temporary under-nutrition or one can enjoy productive public goods investments, but not both.

In this paper we have focused on the potential of FFW to stimulate investment in public goods that may increase future productivity. We motivate the problem with household survey data from northern Ethiopia. We then use a simple theoretical model to lay out the basic analytics of the ambiguous effects of FFW programs on private investment in soil conservation measures. Finally, we illustrate these results using an applied bioeconomic model for one specific area in northern Ethiopia. Our results underscore that the success of FFW investments in stimulating soil conservation, sustainable agricultural productivity increases, and income growth depends crucially on several key conditioning factors, including careful identification of relevant investment projects (a process that typically requires substantive local participation) and of appropriate technology design, local involvement in implementation and maintenance of investments after the project, clear specification of property rights to the investments, implementation only where private capacity or willingness to invest are limited, and timing of projects to minimize labor crowding out effects.

There are, unfortunately, many cases of past FFW projects that did not meet these requirements. For example, the top-down implementation of FFW conservation investments during the 1980s in Ethiopia typically did not involve local people in planning or organization. Farm households themselves had no real influence over the choice of conservation technology nor how it was fit into the landscape on their farms. This caused many to reject the technologies. Many households partly or fully removed these structures from their farms (Shiferaw and Holden, 1998). The NGOs that implement FFW projects typically are humanitarian agencies, many of which do not have the technical skills needed to undertake substantive investment projects right (although there are certainly wonderful examples of well-conceived and well-executed projects).

For example, Smith and Little (2002, p.6) report on a serious bush encroachment problem in the Il Chamus areas of Baringo District. The problem arises from the introduction of *Prosopis spp*. (mesquite in North America) as part of a mid-1980s FFW reforestation project intended to create fuel wood. The problem is that *Prosopis* proliferates quickly, crowds out grasses, and is somewhat toxic for the small ruminants (goats, sheep) on which the Il Chamus agropastoralists depend. The seedpods of the *Prosopis* closely resemble a variety of acacia pod, a common livestock feed, so keeping livestock away from *Prosopis* is difficult, but it hurts their teeth and gastrointestinal systems. Locals deem the tree a serious nuisance and in their view the reforestation effort has actually reduced available grazing area and livestock productivity in the area over the long-term. Smith and Little conclude that this project was "an unmitigated disaster for the [Ng'ambo] community and consequently they are now largely resistant to forestry interventions."

By contrast, more recent FFW projects in Tigray seem to be better designed, and to involve local people more than many FFW projects in other parts of the Horn of Africa. Our analysis of data from 16 communities showed that the crowding in effects of FFW on investment in land conservation were stronger than the crowding out effects. FFW projects may enable farm households to become more forward-looking due to their insurance, liquidity and income effects, leading to longer-lasting benefits than are achieved through poorly targeted transfers.

VI. Conclusions

Market imperfections are a necessary but not sufficient condition to defend the use of FFW projects for short-term relief and/or for promotion of long-term development.

This paper combines empirical, theoretical, and simulation evidence to explore the conditions under which FFW can be effective in stimulating investment in soil conservation structures that are essential to sustainable agricultural productivity and income growth in rural Ethiopia. Our focus is on the long-term effects of FFW projects because most FFW projects in Ethiopia have had long-term development, rather than short-term relief, as their primary goal.

FFW induced investments may prove socially beneficial where private investments are below socially optimal investment levels. This may occur due to the public good nature of the investments (e.g. infrastructure), poverty and liquidity constraints, risk (e.g. tenure insecurity) and intertemporal market imperfections, lack of technical skills and the need for collective action to coordinate investments across farms. FFW projects may provide insurance and relax cash constraints, thereby lowering the discount rates of poor people and making them more forward looking and more able and willing to invest. But careful identification of investment projects is crucial for the success of FFW investment projects. Local involvement in the identification, implementation, and maintenance of the FFW public good investments is very important if de novo FFW investment is to prove durable and if it is not to crowd out private investment.

This paper has focused on how best to minimize crowding out effects and to maximize crowding in effects on private investment in soil conservation. There seem to be several key, basic rules of thumb one ought to follow. First, FFW investments need to be timed so as to minimize competition with other constructive activities, i.e., when the opportunity cost of labor is low for the poor households who are the primary intended beneficiaries of the long-term investments. Second, if FFW projects can protect human capital in the face of idiosyncratic (e.g., farm-specific yield) shocks, then its short and long-term productivity may be enhanced. Likewise, if FFW projects can enhance land productivity through investment in conservation and more productive activities, like planting of perennials, this will also increase the future returns to labor and other inputs and therefore also stimulate their use.

As we illustrated with simulations from a farm-level bioeconomic model and with empirical findings from Tigray in northern Ethiopia, FFW can crowd in private investments in soil conservation and improve the welfare of people in the longer term. It is, however, a skill and knowledge-demanding task to design and implement efficient FFW programs. There is considerable room for improvement of existing programs.

Appendix.

Bioeconomic Model: Detailed model description

Representative households (for household groups) are assumed to maximize welfare;

$$U = \int_0^T \rho^t u_t dt = \sum_0^T \rho^t u_t \qquad \text{(A1)}$$

through a time-separable utility function over the time horizon T. Utility in period t is discounted by the discount factor, $\rho^t = \left(\frac{1}{1+\delta}\right)^t$, where δ is the utility discount rate.

Utility in period t is represented by a constant partial relative risk aversion utility function[15];

$$u_t = (1-\mu)Y_t^{1-\mu} + \mu - 1 \quad \text{(A2)}$$

where μ is the partial relative risk aversion or the absolute value of the elasticity of marginal utility of certainty equivalent full income, Y_t, which is equal to;

$$Y_t = E(I_t) - \psi_{1t} - \psi_{2t} \quad \text{(A3)}$$

where $E(I_t)$ is expected normalized full income in period t, ψ_{1t} is a downside risk premium related to obtaining formal credit and ψ_{2t} is a risk premium related to drought risk in the *belg* season. Full income was normalized by the poverty line full income (γ_t), while the risk premia were normalized by the poverty line income (ζ_t)[16], excluding the value of leisure;

$$E(I_t) = E(y_t)/\gamma_t \quad \text{(A4)}$$

where $E(y_t)$ is the expected full income[17] in Ethiopian Birr in period t. Subsistence leisure, $Le_{\min}$, is valued at the minimum wage rate, $w_{\gamma t}$, required for the work force of the household, taking out only the subsistence level of leisure, to generate an income exactly equal to the poverty line income;

$$w_{\gamma t} = \zeta_t / L_{\max} \quad \text{(A5)}$$

where $L_{\max}$ is the maximum time available for work and ζ_t is the poverty line income excluding the value of leisure. The time endowment, F_t, of the household may then be formulated as follows;

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[15] This type of utility function has been used by Binswanger (1981) and others in empirical studies of risk preferences of farm households. Its simple form makes it attractive also for modelling purposes as risk aversion is captured by a single parameter.

[16] Based on Dercon and Krishnan (1996) who develop consumption-based poverty lines for rural Ethiopia, including the study area. The poverty line is therefore treated as exogenous in the model.

[17] Computed based on probabilities of drought, hailstorm/frost damage and expected prices.

$$F_t = Le_{\min} + L_{\max} \quad \text{(A6)}$$

and poverty line full income is;

$$\gamma_t = w_{\gamma t} F_t \quad \text{(A7)}$$

This formulation gives utility equal to zero if the household has $Y_t = 1$, negative utility if Y_t is below the poverty line ($Y_t < 1$), and positive utility if $Y_t > 1$. Population growth affects the time endowment and poverty line income causing both to grow proportionally over time.

Market characteristics

The model incorporates the following market characteristics. We leave out the subscript for year to simplify notation.

- Credit market

Formal credit in kind (for fertilizer) that is constrained from above (equation A8);

$$p_f Fe = C_f \leq \overline{C}_f \quad \text{(A8)}$$

This credit must be repaid after harvest. It may also be possible to obtain informal credit within the village at a higher rate of interest (equation A9);

$$C_i \leq \overline{C}_i \quad \text{(A9)}$$

This credit must also be paid back within the same year.

- Labor market

Households are assumed to have constrained access to off-farm employment and the wage rate in the labor market varies across seasons. Households may also hire labor for work on the farm. A price band is introduced such that the wage rate for hiring labor is about 10-20% higher than the wage rate obtained while working off farm. The household shadow wage in season p, w_p^*, should fall between the buying wage and the selling wage when households do not participate in the labor market (equation A10).

$$w_{sp} \le w_p^* \le w_{bp} \quad \text{(A10)}$$

Households may sell labor in some seasons and buy labor in other seasons, however. The households are assumed to be drudgery averse (Chayanov, 1966; Nakajima, 1986). This implies that the shadow wage rate is an increasing function of the time worked and that there is a trade-off between income and leisure. Indifference curves between income and leisure will be upward sloping and convex in labor and income space. Household preferences for leisure in income-labor space are formulated as a reservation wage curve that is convex and upward sloping and calibrated to fit the observed seasonal labor supply/leisure demand and wage rates in the area;

$$w_p^* = \beta_1 + \beta_2 D_p + \beta_3 (D_p - \beta_4)^2$$
$$D_p = L_p^* / W$$
$$L_p^* \le \overline{L}_p$$
$$L_p^* = L_{pF} - L_{pH} + L_{pO} + L_{pFFW} \quad \text{(A11)}$$
$$L_{pF} = L_{pC} + L_{pL}$$
$$L_{pT} = L_p^* + L_{pE}$$

where βs are parameters, D_p is the seasonal family labor divided by the household labor force (W), $\overline{L}_p$ is the maximum time which is available for work[18], L_{pC} is seasonal family labor in crop production, L_{pL} is seasonal family labor in livestock production, L_{pO} is seasonal off-farm family labor, L_{pFFW} is seasonal FFW labor, L_p^* is total seasonal family labor, L_{pF} is total seasonal on farm labor and L_{pH} is hired labor, L_{pT} is the total seasonal time endowment, and L_{pE} is the seasonal leisure time. Labor for conservation (building of new structures, maintenance of structures, and

[18]Maximum time available for farm work is determined by subtracting religious holidays from the total number of days in the period. Work on the farm is not permitted on religious holidays.

removal of old structures) is included in L_{pC} unless it is carried out through FFW. The shadow wage is determined by the intersection of the wage equation with the labor constraint.

- Land market

There is an informal rental market for land in the area. This market is interlinked with the output market as the rent is paid in the form of a share of the output (share tenancy).

- Oxen rental market

There is an imperfect market for oxen renting in the model. Imperfections are due to moral hazard problems and seasonal timing constraints.

- Seed market

It is assumed that markets for seed function well but a price band is included making the price of purchased seeds 5% higher than the selling price. Households also have the option of storing seeds from their own harvest for the next season.

- Output markets

Output markets are assumed to function well but a price band is included such that the purchase price is assumed to be 5% higher than the selling price.

Land degradation and conservation

The main forms of land degradation in the model are soil erosion and nutrient depletion. Plot level soil erosion per unit of land *(se_a)* is a function of soil type, soil depth and slope (land type class, *A*), rainfall (ψ_r), crop choice *(Cr)*, and use of conservation technology (Ψ);

$$se_{Aq} = se(A_q, \psi_r, Cr, \Psi) \qquad \text{(A12)}$$

Soil erosion rates were determined based on field experiments carried out by the in the study area (Shiferaw and Holden, 2001). Farmers may influence soil erosion rates through their crop choice/land use or by building or removing conservation technologies on the different types of land. The model implicitly evaluates the profitability of erosion control on the different types of land (soil type depth and land slope). Soil erosion affects soil depth (sd) through a transition equation;

$$sd_t = sd_{t-1} - \tau se_t \qquad \text{(A13)}$$

where τ is a conversion factor.

Nutrient depletion in the model focuses on nitrogen and phosphorous which are considered to be the main nutrients limiting crop production in the area. The balance or depletion per unit of land at the plot level depends on the land/soil type, the stock of nutrients in the soil, crop choice, conservation technology use, yield, application of fertilizer and manure, and the release of nutrients from the soil. Nutrients are also lost through eroded soil and this soil is richer in nutrients than the soil remaining behind[19]. Release of nitrogen from the soil is assumed to depend on the stock of nitrogen[20]. The change in N stock is given by;

$$N_{t+1} = N_t - \varphi(N_t - \eta(se_t)) - \eta(se_t) \qquad \text{(A14)}$$

where N is nitrogen, φ is the share of nitrogen mineralized in each period and η is the nitrogen composition of the soil. The change in plant available N from period to period (ϕ) due to nutrient depletion is computed as;

$$\phi = \varphi(N_t - N_{t-1}) \qquad \text{(A15)}$$

The reduction in plant available nitrogen is included in the production function (equation A17 below). The nutrients in animal manure are released over two years

[19] An enrichment factor of 2 is used for nitrogen.

[20] We assume that 1% of the nitrogen stock is released each year.

with 60% being released in the first year and the rest in the following year. The effects of nitrogen and rooting depth depletion on yields are therefore included. Households may decide to conserve their land by introducing conservation structures (graded soil/stone bunds). Only labor is needed as an input for this, 100-120 working days per ha, depending on the slope of the land. Maintenance of the structures requires an additional 15-20 working days per year and ha. Shiferaw and Holden (1998) found, based on econometric analysis of plot level data collected in 1994, that poor and land-scarce households were more likely to dismantle conservation structures introduced through food-for-work in the early 1980s. Therefore, in our model households may also decide to remove conservation structures and this is estimated to take only 25% of the time required for construction. The conservation structures may occupy some productive land; therefore reducing the effective cropping area and this may reduce initial crop yields. Two formulations of the model are used here; a) where the yield loss is negligible, and b) where initial yields are reduced by 5-10% depending on the slope of the land. Building or removing conservation structures may therefore affect long-term as well as short-term yields. The long-term effect goes through the impact on land degradation and the feedback through crop yields.

Crop production

Yields of different crops are functions of soil type, soil depth, slope, application of fertilizer and manure converted into nitrogen (*N*) and phosphorus *(P),* and conservation technology (Ψ). The intercept of the yield *(yi_{int})* function, suppressing the crop type and year, is a function of soil type *(A_q)* and soil depth *(sd)*;

$$yi_{int} = yi(A_q, sd) \qquad \text{(A16)}$$

The impact of soil depth on crop yield intercepts was estimated econometrically using farm level experimental data from the study area and testing alternative functional forms[21]. The final yields, including inputs, were also estimated econometrically[22];

$$yi_{Aq} = yi(yi_{\text{int}}, \Psi, N_{F,} \phi, P_F) \qquad \text{(A17)}$$

where N_F is fertilizer and manure nitrogen added ϕ is the change in available mineralized nitrogen, and P_F is phosphorus added through fertilizers and manure. Yields may be influenced by conservation technologies (Ψ) as conservation structures take up some part of the land, the structures may harbor pests, they may reduce runoff and leaching and, of course, erosion. The short term effect on yields of the use of conservation technologies is therefore ambiguous but over time yields under conservation should decline less rapidly than without conservation.

Crop choice will depend on the profitability (prices and yields), food, fodder, security, labour demand and distribution, the suitability of the different types of land, and access to inputs such as traction power, fertiliser and property rights or rental arrangements for land. The crops grown in the area include barley, wheat, field pea, horse bean, lentils and linseed. Land may also be planted with eucalyptus trees, grass or left fallow. All the crops may be grown in the *meher* season but only barley, field pea and lentils are grown in the *belg* season.

The model also contains livestock activities but we refer to Holden and Shiferaw (in press) for more details on this. Furthermore, the model contains annual full income and cash constraints.

VII. References

[21] See Shiferaw and Holden (2001) for details.

[22] Using data from FAO fertiliser demonstration plots for the Debre Berhan area, assessing alternative functional forms.

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Table 1. Types of food-for-work activities in which households have participated

FFW activities (% participation among surveyed households)	
Dam construction	22
Stone terrace construction	18
Soil and water conservation	9
Road construction	9
Soil bund construction	6
Tree planting	4
Check dam construction	3
Gully control	3
Bench terraces construction	2
School construction	2
River diversion	1
Other house construction	1

Table 2: Types of mass mobilization activities during 1997

Types of Activities	% Participated
Conservation on communal land	47
Conservation on private land	25
Road construction	1
Other work	10
All activities	83

Table 3: Types of assistance needed to reduce the land degradation problem

Type of Assistance	Response %
Technical assistance and labor mobilization	56
Technical assistance	26
Technical assistance and conflict resolution	15
Technical assistance and other assistance	1
Conflict resolution and labor mobilization	1
Conflict resolution and other assistance	0
Labor mobilization	1
Other assistance	0

Table 4: Role of public and private conservation investments

Private investment	Public-led conservation investment Yes	No
Number plots with stone terraces		
Yes	173	174
No	527	650
Number plots with soil bunds		
Yes	106	68
No	594	756
Intensity of stone terraces		
Yes	71.5	71.0
No	5.4	0.0
Intensity of soil bunds		
Yes	111.3	93.8
No	17.8	0.0

Intensity of conservation technologies is measured in meters on structure per ha of land. Yes and No in the rows indicate whether there are private investments or not on the plots, and similarly for public investments in the Yes and No columns.

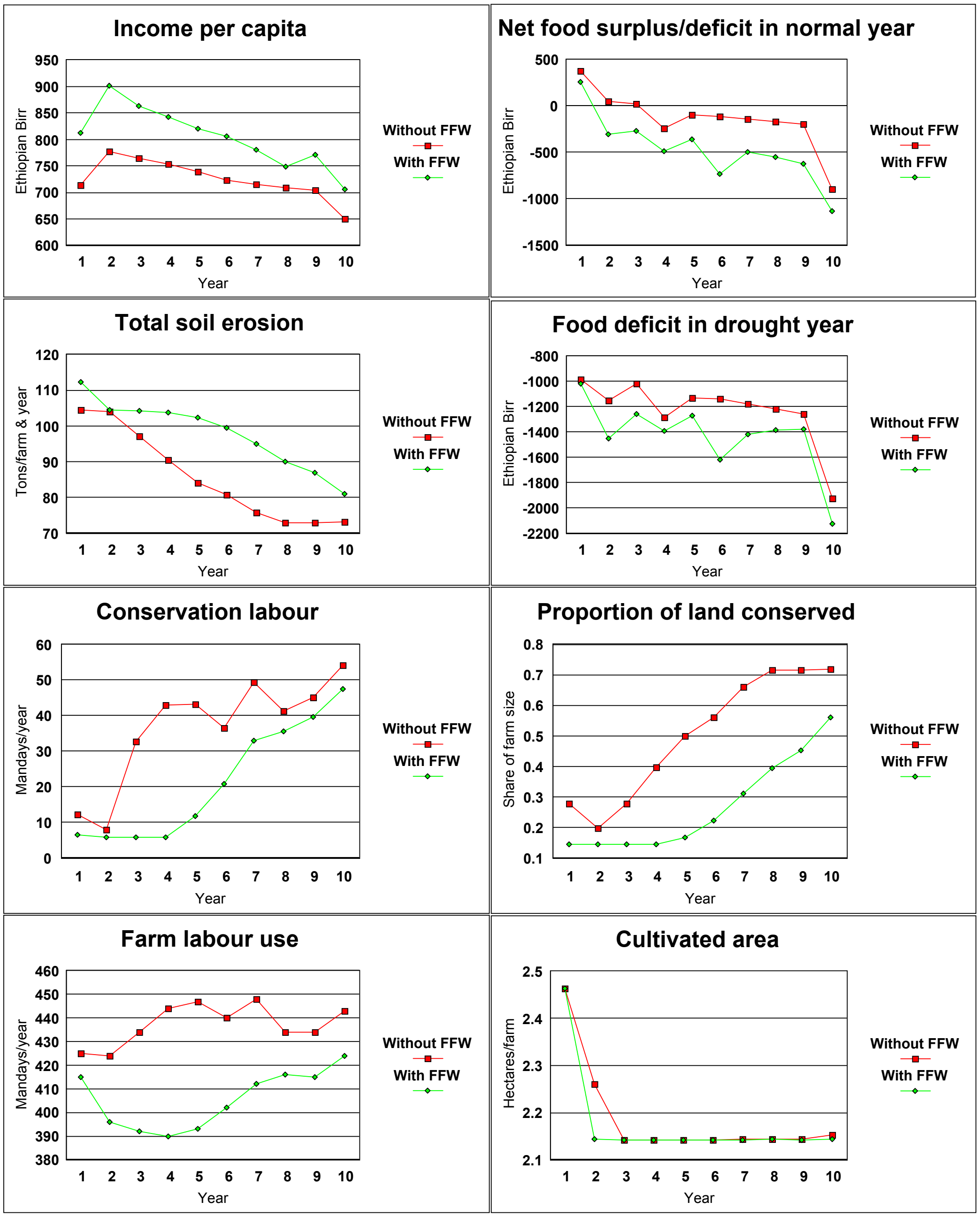

Figure 1. The impact of introducing FFW when FFW is not used for conservation, labor market access is constrained and land conservation does not reduce initial yields

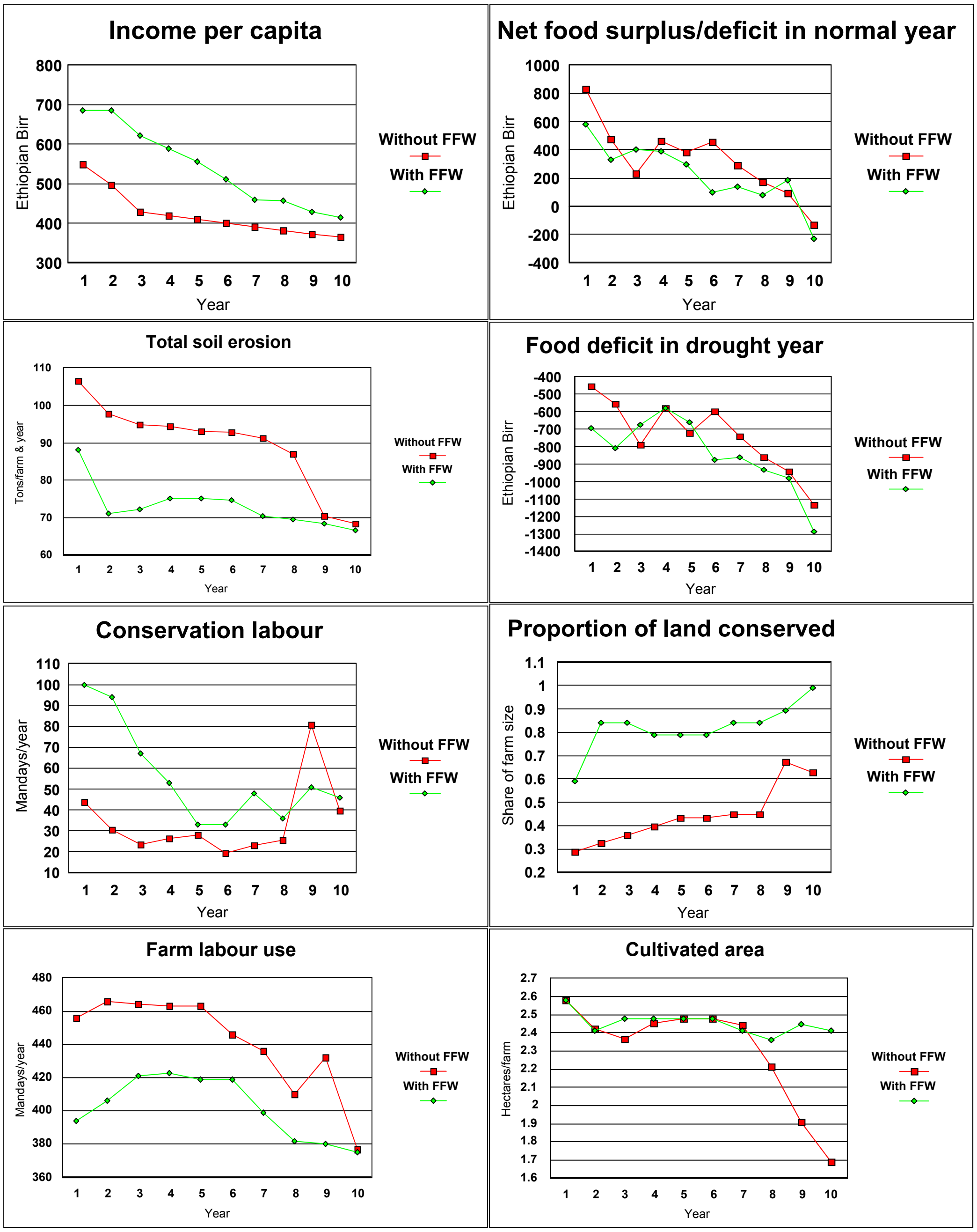

Figure 2. The impact of FFW when FFW is used for land conservation, labor market access is constrained and conservation does not reduce initial yields

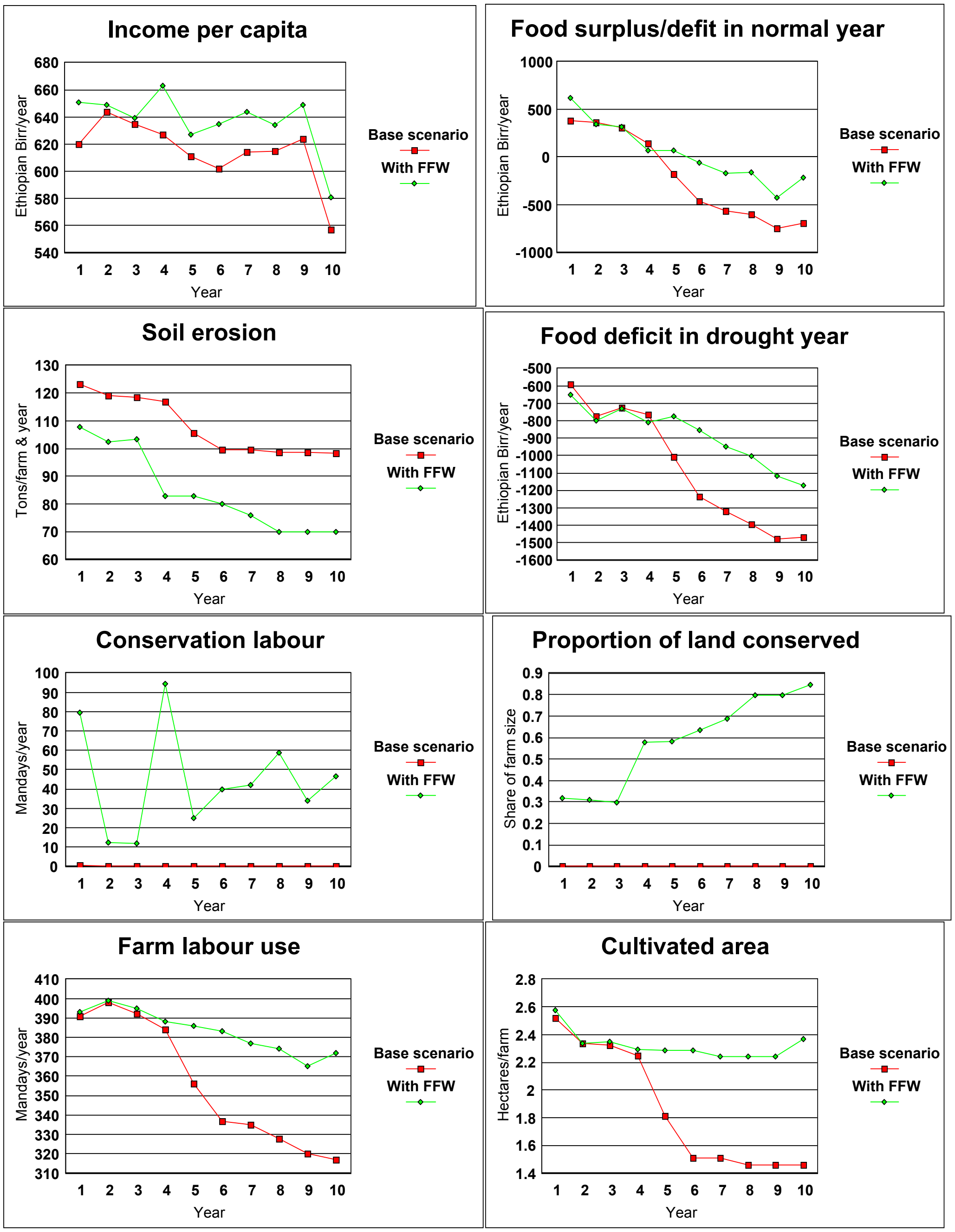

Figure 3. Effects of FFW when conservation reduces initial yields and access to off-farm employment is unconstrained

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