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Introduction

Secure access to food, adequate in quantity and quality, is becoming increasingly problematic for many. The number of food insecure is rising worldwide, reaching more than 1 billion according to the latest estimate (FAO 2009). Falling incomes, in part due to the global financial crisis, and continuing high food prices are proving devastating for those whose livelihoods are the most precarious. Climate change and variability are contributing to food insecurity in Africa and other regions and will do so increasingly in future. The most vulnerable are those dependent on highly seasonal, rainfed agriculture (IPCC 2007).

The impact of rising levels of hunger on human health and particularly major diseases such as HIV/AIDS, tuberculosis and malaria is of wide concern. However, our ability to predict with confidence is limited. With respect to HIV/AIDS, much of what is known about the effect of hunger and other facets of poverty comes from cross-sectional or longitudinal studies of limited duration and with few survey rounds that shed little light on dynamic effects, whether trends or cycles, and give little insight into the impact of major shocks (Gillespie et al. 2007). The fact that hunger is both a cause and a consequence of HIV/AIDS further limits the ability of these methods to disentangle the effect of change in any one.

The evidence reported here brings new light to bear on this question. It assesses the 2001-03 famine in Malawi as a country-scale natural experiment on the effect of hunger on the dynamics of HIV. The famine has been described as a particularly severe seasonal hunger event (Devereux et al 2008) and thus it also brings into sharper relief the links between seasonal hunger and HIV risks.

Mervyn Susser (1981) defined natural experiments as "observational studies of the effects of sharp, well-defined but unplanned changes in which exposed and unexposed comparison groups can be readily identified". The famine in Malawi can be fairly well delimited in time and, beyond exposed and unexposed, the degree to which different groups were exposed can also be defined. As described below, the extent of hunger varied among rural areas and between them and urban areas. Hunger was also experienced differently by men and women. Natural experiments have a long history in epidemiology and in particular have provided crucial insights into the consequences of sharp reductions in food intake imposed on whole populations or large groups (Apfelbaum 1946, Stein et al. 1975, Franco et al. 2007). While the "interventions" that underlie natural experiments have often been of a kind or scale that would be otherwise impossible or unethical to implement, their analysis has in several cases suggested important intervention opportunities. In the final section, I discuss the implications of the Malawi famine natural experiment for the conception of HIV prevention and that of related health conditions.

[1] Applied Ecology Associates, Wageningen, The Netherlands. Paper presented at the Future Agricultures International Conference "Seasonality Revisited", IDS, Sussex, July 8-10, 2009.

The Famine The origins of the famine can be traced to three converging factors that combined to deprive rural households of their entitlements to food. First, the maize harvest of 2001 was 32% below that of the year previous and the subsequent harvest of 2002 was a further 8% less. Flooding and poorly distributed rainfall early in the growing season were largely responsible; neighbouring countries – Mozambique, Zambia and Zimbabwe – were also affected. The production shortfall in Malawi was not exceptional but its impact on food security was magnified by several developments that had left rural Malawians dangerously vulnerable to the fate of the main annual maize harvest: the erosion of crop and livestock diversity, in part as a result of policy that favoured maize; the dismantling of state marketing structures and support programs, increasing their exposure to volatile markets for farm inputs and for maize itself and prolonged under-investment in human capital and rural infrastructure, notably irrigation. AIDS exacerbated this vulnerability: dependency ratios rose in households enduring the illness and then death of prime-age adults or taking in orphans, while capital resources were depleted by prolonged illness and funerals (Devereux 2002, Devereux and Tiba 2007, Frankenberger et al. 2003).

Second, increasing numbers of rural households had, in the years leading up to the famine, become unable to feed themselves from one year to the next from what they harvested and were forced to rely on casual labour (*ganyu*). Bryceson (2002) describes this process as depeasantization. The process was self-reinforcing since by working on others' fields they were unable to tend their own in a timely fashion, further undermining their production. The two poor harvests in 2001 and 2002 exacerbated this trend, pushing larger numbers of farming households, not just the poorest, into the search for *ganyu* while at the same time reducing the number of farmers who were hiring. As a consequence, wage rates fell and working conditions deteriorated (Shah et al 2002, Ellis et al. 2003, MVAC 2003).

Third, the price of maize rose steeply through the second half of 2001, by February 2002 reaching 2-6 times that of the previous year. In most markets a kilo of maize cost more than the daily *ganyu* wage. The poor harvest of March-May 2002 brought little relief and prices remained high in most areas through the rest of 2002. Institutional responses contributed to the upward pressure on food prices. The Strategic Grain Reserve (SGR), intended to buffer production and market fluctuations, was sold off, much of it allegedly to private traders who hoarded it until prices had risen. The government purchased maize from South Africa but logistical constraints delayed its arrival and the ceiling price imposed discouraged traders from transporting it to rural communities where the needs were greatest. The response of international donors was also delayed, in part because of poor relations with the government over the management of the SGR (Devereux 2002, IDC 2003).

Deaths from hunger and cholera were reported in several parts of the country early in the year (Devereux 2002, WHO 2002). A consortium of non-governmental, government and international agencies began regular monitoring of the food and nutrition situation in the rural areas of Malawi's 27 districts in the second year of the crisis. They found that between July-August and November-December 2002 (the beginning of the hungry period before the main maize harvest), the proportion of rural households regularly taking fewer meals per day increased from 60% to 76% and those going entire days without food from 32% to 48%. Households headed by women, those with few assets and those harbouring a chronically ill adult (a proxy for AIDS) made more drastic cuts in consumption. Based on the November-December survey, it was estimated that 31% of rural Malawians would need food assistance over the following 3 months, unevenly spread but substantial in all regions (MVAC 2002, 2003).

Though the food situation was not monitored in the towns and cities, the crisis was evidently less acutely felt there. Households with a non-agricultural income were not directly affected by the loss of production and the scarcity of *ganyu* employment. Maize was also more reliably available in urban markets and its price there less volatile in part because the low support price discouraged traders moving it up-country (Devereux 2002). For example, at the market's peak in February 2002, the price in Lilongwe was 22% below the average in other markets in the Central Region (data from FEWSNET 2002). Similar differences existed in the other major cities Blantyre and Mzuzu. These developments reinforced existing disparities of income, education, nutrition and access to health services between the cities and rural villages. These disparities also existed between the villages and towns, including the district administrative centres (*bomas*) (World Bank 2007).

Within the villages, hunger was also unequally experienced. In particular, those with the largest land holdings and those with other sources of income whether from trading or from salaried work, especially teachers, health workers and other civil servants, were much less affected. They were in a position to offer *ganyu* and benefitted from the lower wage rates as well as from farmers' distress sales of livestock and other assets. There is also evidence of poorer farmers leasing parts of their land to satisfy immediate needs (Bryceson 2006).

Hunger and HIV risk Several typical situations can be identified wherein people's exposure to HIV or their risk of infection once exposed is increased by hunger. In Malawi, there is evidence that the famine pushed rural Malawians further into these existing and familiar "situations of risk".

The first of these is transactional sex, in extreme situations often referred to as survival sex. Hunger, along with other aspects of poverty, is frequently cited by sex workers as a reason for having taken up that work and as undermining their ability to insist on their clients using condoms (Oyefara 2007, Campbell 2000). Hunger also influences decisions of women in the general population who engage in transactional sex on an occasional basis. In Botswana and Swaziland, women who claimed not having had sufficient food at some point in the previous year were more likely to report having exchanged sex for money, food or other resources. They were also more likely to report a context that increased the infection risk of these encounters: having non-primary partners 10 or more years older, using condoms inconsistently with them and lacking control in their sexual relations. Among men, only inconsistent condom use was significantly associated with insufficient food (Weiser et al 2007).

There is only limited documentary evidence regarding the prevalence of survival sex in rural areas and even less specifically relating it to seasonal food and livelihood insecurity. However, this is more likely due to the difficulty in broaching this topic in a research context and to the interests of researchers than it is to the frequency of the phenomenon itself. In seven districts of Andhra Pradesh, India, interviews with male and female sex workers reveal that many turn to it when employment on-farm or in rural warehouses is not available (George et al. 2005). In Kolar and Chitradurga Districts, Karnataka, the number of rural women selling sex in public places such as markets is said to increase markedly during the hungry season before the main harvest (MYRADA, Soukhya project staff, pers. comm.).

In Malawi before the outbreak of the famine, the sale or exchange of sex for food or gifts on an occasional basis by women with few other subsistence options was recognized as an important situation of infection risk (Government of Malawi 2001). Men and women interviewed in the Central Region before the famine indicated transactional sex involving poorer women and better-off men was common, particularly after the tobacco harvest (Shah et al. 2002). As maize prices rose steeply in the last half of 2001, concern was voiced about the impact on HIV incidence (Ngwira et al. 2001). A report early in 2002 from Mchinji, one of the hardest hit districts, spoke of increasing numbers of women exchanging sex for food or cash (Kamowa 2002). A rapid survey in 10 districts in December 2002 found that 15% of young women and 6% of older women acknowledged exchanging sex for food, while 73% of young men and 53% of older men claimed to have provided food for sex during the crisis period (UNCT 2002), numbers that should be considered no more than suggestive given the difficulty in assessing this sensitive matter through formal interviews (Jeejeebhoy et al. 2003). Informants in an ethnographic study in the Central region following the famine considered women's transactional sex to be an expanding arena of sexual activity and reported that provision of sexual services was being incorporated into *ganyu* contracts. This tendency was said to have escalated during the famine (Bryceson et al. 2004, Bryceson 2006).

Early marriage is another situation of risk for women. Young women married to older men are at heightened risk of exposure to HIV and STIs because their partners are more likely to be infected than men their own age; physiological immaturity enhances the risk of infection following exposure (Bruce and Clark 2004). In South India, food and livelihood insecurity are often among the reasons families contract early marriages for their daughters (Kelkar 2004). In Malawi's Central Region, poor rural women, particularly orphans, saw early marriage as one of the few means to escape their predicament (Bryceson et al. 2004). During the famine, several reports emerged of girls and young women being forced into early marriage (UNCT 2002, Munthali 2002).

Distress migration is a common situation of risk, more visible and less sensitive than survival sex and early marriage. Migration of single adults in search of work is often an early response to distress. Typically this has involved young men, but increasingly in West and Southern Africa young women (Crush 2005, Adepoju 2005). At their destination, distress migrants often face poor working and living conditions and women are frequently exposed to sexual abuse (Mosse et al. 2002, Gomez et al. 2008). Separated from partners and family, migrants are commonly found to be more likely to engage in non-marital sex and to be HIV-infected than are non-migrants (Pison et al. 1993, Decosas et al. 1995, Mehendale et al. 1996, Lurie et al. 2003).

In Malawi, seasonal migration was common before the famine, particularly by men to tea, coffee and tobacco estates that have large labour demands. A dependent population of occasional or commercial sex workers typically settled nearby, creating a focus of HIV transmission (Ngwira et al. 2001). In Mchinji district early in 2002, adults were reported to be leaving in search of food or work on agricultural estates, in towns, in neighbouring districts and across the border in Zambia (Kamowa 2002). Migration in search of food from maize-growing to cassava-growing areas was said to be common (Devereux 2002, WFP 2003) – cassava being more tolerant of harsh conditions. Women from rural areas near Lilongwe sought *ganyu* on the city's periphery, for example at grain mills, where they faced sexually abusive working conditions (Bryceson 2006). A survey of 1,200 rural households in 2002 found that 39% had members migrating in search of food or work (Devereux et al. 2003 cited in Devereux forthcoming).

Hunger and malnutrition may also affect the risk of infection once a person is exposed to HIV. The evidence as regards primary (heterosexual) infection is at this point suggestive and has been summarized by Stillwagon (2006). Malnutrition in general compromises immune function although a direct effect on HIV infection has not been unequivocally shown. Evidence is clearer that it increases the risk of infection by sexually transmitted diseases other than HIV which in turn have been shown to facilitate infection by HIV. Malnutrition also increases the viral load in HIV positive individuals, increasing the risk of transmission. Both effects are exacerbated by prior infection with malaria, schistosomiasis, helminthic and filarial parasites.

These situations of risk provide a basis for hypotheses about the impact of the famine on HIV infection rates. Here I concentrate on the effects on women because regular HIV surveillance has only involved them. Hunger-induced survival sex and early marriage leading to increased exposure to HIV and/or hunger increasing the likelihood of infection once exposed would, in aggregate, be reflected in increased incidence and prevalence of HIV in rural areas, with the effect proportional to the extent of hunger in the population and its duration. The effect of early marriage would be visible in a much greater increase in infection among younger than older women while survival sex, which apparently involved both older and younger women, would be reflected in a more even increase. The fact that, as discussed above, some rural men were little affected by the famine or even benefited (those with larger holdings or with non-agricultural sources of income) would augment these effects. The disparities would increase the incentive for hungry women to engage in survival sex or for young women or their families to contract an early marriage. They might also alter the shape of sexual networks by creating more asymmetrical relationships (e.g. a man able to provide *ganyu* having sex with a number of workers) and more concurrent relationships (e.g. the man maintaining relationships with his wife and one or more of the workers for some time). Both effects have been shown to hasten HIV transmission and the latter to increase equilibrium prevalence (Garnett and Anderson 1996, Morris and Kretzchmar 1997, Halperin and Epstein 2004).

The likely effect of hunger-induced migration is more difficult to predict. Much depends on the pattern of migration it produced and how it altered existing patterns. The available information is sparse: migration by adult men and women was said to have occurred from hard pressed rural areas to less affected rural areas, towns, cities and neighbouring countries. There is little to indicate how long people remained, however evidence from other famines suggests that not all migration is temporary (von Braun et al. 1998). To the extent that was true of Malawi in 2001-03, one could expect that the famine affected not only the distribution of HIV (epidemiology) but also that of people (demography). That the famine was less acutely felt in the towns and cities would be expected to increase the "pull" on migration from the villages, while the "push" would have been greatest where rural hunger was most severe.

Methods

Food insecurity The extent of rural food insecurity was assessed thru household survey undertaken by the above-mentioned consortium. In August 2002, 1128 households were sampled in 81 villages in all 27 districts of Malawi and asked about their access to food from stocks and expected harvest, income, gifts and purchases in the coming months. An algorithm that took account of the household's food requirements, its access to food and different price scenarios was then used to estimate whether the household would experience a significant food deficit and require assistance in the December 2002-March 2003 period, the peak of the lean season; from this the proportion of rural households expected to need assistance by district was calculated (MVAC 2002). I refer to this proportion as "the extent of rural hunger". Food assistance did in fact reach many and, together with stabilized prices, appears to have prevented the mass starvation-linked deaths experienced the year previous (MVAC 2003b). Nonetheless, the food that actually reached those targeted was, for a number of reasons, often much less than planned (WFP 2003). Here I draw on the estimates for the district in which a surveillance site is located. For Mzuzu city, which is not part of any district, I take the average of the estimates for the two districts that surround it, Mzimba and Nkhata Bay.

Migration The nationwide Integrated Household Survey (IHS) conducted in 2004 and early 2005 (n=10,777 households) asked whether members had moved to their present residence within the last 5 years and if so when and from where. From this data the prevalence and timing of migration in different directions especially rural-urban and rural-rural was calculated for different age-gender classes.

HIV prevalence In Malawi, HIV prevalence has been monitored annually or biennially since 1994 at 19 sites in antenatal clinics (NAC 2003). Eight of these sites are rural, located in village health centres (village population not available); 8 sites are semi-urban, located in hospitals in district *bomas* (2002 population 10,000-31,000; NSO 1998, 2008). The rural and semi-urban sites were established in randomly selected districts, stratifying for region. Three clinics are urban, purposely selected and located in hospitals or health centres in the three largest cities of Mzuzu, Lilongwe and Blantyre (2002 population 103,000, 521,000 and 561,000, respectively).

I make use of the 1999/2000 surveillance round (begun 28 November 1999, midpoint 7 January 2000, 95% completed 1 February 2000), approximately 18 months before the steep rise in maize price, and the 2003 round (begun 4 January 2003, midpoint 11 March 2003, 95% completed 3 October 2003), overlapping the peak of the lean season in the 2nd year of the crisis and the post-harvest period when food was more readily available. The 2001 round cannot be used because some women were sampled before and some after the rise in maize price. One semi-urban site, Nkhotakota, is discarded because its results in 2003 were deemed unreliable (NAC 2003).

On each surveillance round, clinic staff select a consecutive sample of women on their first antenatal visit, test their blood anonymously for HIV using an enzyme-linked immunosorbent assay and record their personal characteristics (NAC 2003). This analysis draws on women's age, education status, occupation and partner's occupation, if co-habiting. Because the occupation codes for 1999/2000 are missing, it was only possible to infer the code for "farmer", by far the most common occupation in Malawi. In what follows, a woman who gave her occupation or her partner's as "farmer" is considered a farmer.

Table 1 summarizes characteristics of the surveillance sites and the women attending these clinics. Rural clinics, not surprisingly, attract predominantly farmers, urban clinics mostly non-farmers and semi-urban clinics intermediate proportions. Education levels are lower at the rural and semi-urban than at urban clinics.

Figure 1 shows the trends in HIV prevalence since 1994. Prevalence peaked in 1996 at urban sites, in 1999/2000 at semi-urban sites and in 2003 at rural sites. Prevalence and trends have been similar at the urban and semi-urban sites since 1999/2000; these "non-rural" sites are analysed together in what follows.

[Table 1 and Figure 1]

Analytical methods Multilevel analysis is increasingly employed in epidemiology and public health to assess simultaneously the contribution to ill-health of factors operating at the individual and group or neighbourhood levels, as well as their interaction (Bingenheimer and Raudenbush 2004, Diez Roux and Aiello 2005). I use multilevel, random intercept models (Goldstein 2003) to analyse the contribution of contextual factors at the surveillance site level (rural or non-rural setting, the extent of rural hunger in the district in December 2002-March 2003) and compositional factors at the individual level (the woman's age, occupation and educational attainment) and their interactions, to the probability of a woman being HIV-infected and to the change in this probability over the course of the food crisis. The serostatus of the *i*th woman in the *j*th site in 2003, y_{ij}, is a binary variate that takes the value 1 (positive) with probability $\pi 03_{ij}$. The logit link is used to relate this probability to a linear function of factors and covariates. Residuals at the individual and site level are assumed to follow binomial and normal distributions, respectively, with mean 0. I focus first on the site level, estimating a model of the form:

$$\text{logit } \pi 03_{ij} = \text{logit } \pi 99_j + \beta_{0j} + \beta_1 \text{ rural}_j + \beta_2 \text{ rural}_j \cdot \text{hunger}_j + \beta_3 \text{ nonrural}_j \cdot \text{hunger}_j + \mu_{0j} \quad (1)$$

where $\text{logit } \pi 03_{ij} = \log [\pi 03_{ij}/(1- \pi 03_{ij})]$ is the log odds of a woman being positive in 2003 and logit $\pi 99_j$ the log odds of being positive averaged over all women at the *j*th site in 1999/2000. Subtracting the latter term from both sides makes the dependent variable the log of the odds ratio of being HIV infected in 2003 vs. 1999/2000 (adapting an approach suggested by Ukoumunne and Thompson 2001). β_{0j} is the fixed part of the intercept and μ_{0j} its site-specific residual. $rural_j$ and $nonrural_j$ are dummy variables taking the value 1 when the site is rural or non-rural, respectively, and 0 otherwise. β_1 is thus the additional fixed part of the intercept at rural sites, while β_2 and β_3 are the linear coefficients of rural hunger in the district surrounding rural and non-rural sites, respectively. The $hunger_j$ variable was arc sine-transformed and centred on its overall mean. Quadratic terms in $hunger_j$ were also fitted to test for non-linear relationships.

I then fitted a model that included all individual-level factors and their interactions with rural hunger:

$$\text{logit } \pi 03_{ij} = \text{logit } \pi 99_j + \beta_{0j} + \beta_1 \text{ rural}_j + \beta_2 \text{ rural}\cdot\text{hunger}_j + \beta_3 \text{ nonrural}\cdot\text{hunger}_j +$$

$$\boldsymbol{\beta_4} \text{ rural}\cdot\mathbf{X}_{ij} + \boldsymbol{\beta_5} \text{ nonrural}\cdot\mathbf{X}_{ij} + \boldsymbol{\beta_6} \text{ rural}\cdot\mathbf{X}\cdot\text{hunger}_{ij} + \boldsymbol{\beta_7} \text{ nonrural}\cdot\mathbf{X}\cdot\text{hunger}_{ij} + \mu_{0j} \quad (2)$$

$\boldsymbol{X_{ij}}$ is the vector of categorical variables age, education and occupation, $\boldsymbol{\beta_4}$ and $\boldsymbol{\beta_5}$ are the vector of coefficients of their main effects at rural and non-rural sites, respectively. These coefficients indicate the extent to which the log odds of infection for women in that class in 2003 exceeded or fell short of the mean log odds for all women at the site in 1999/2000, controlling for the site-level factors and interactions. $\boldsymbol{\beta_6}$ and $\boldsymbol{\beta_7}$ are the vector of coefficients of the interaction of age, education and occupation with rural hunger at rural and non-rural sites, respectively; these indicate the extent to which, relative to the 1999/2000 mean, the log odds of infection for women in that class in 2003 varied with the level of rural hunger in the district.

For comparison, I fitted a model (3) with the log odds of a woman being infected in 2003, logit $\pi 03_{ij}$, as the dependent variable. This included only the individual-level factors (age, education and occupation) as independent variable i.e. without logit $\pi 99_j$ and $hunger_j$.

To understand how the composition of the antenatal sample at the sites changed over the crisis, I estimated models of the form of (1) and (2) but with log odds of a woman being a farmer in 2003 logit $\varphi 03_{ij}$ as dependent variable i.e. irrespective of HIV status, and with logit $\varphi 99_j$ the log odds of being a farmer averaged over all women at the *j*th site in 1999/2000 on the other side of the equation:

$$\text{logit } \varphi 03_{ij} = \text{logit } \varphi 99_j + \beta_{0j} + \beta_1 \text{ rural}_j + \beta_2 \text{ rural}_j \cdot \text{hunger}_j + \beta_3 \text{ nonrural}_j \cdot \text{hunger}_j + \mu_{0j} \quad (4)$$

$$\text{logit } \varphi 03_{ij} = \text{logit } \varphi 99_j + \beta_{0j} + \beta_1 \text{ rural}_j + \beta_2 \text{ rural}\cdot\text{hunger}_j + \beta_3 \text{ nonrural}\cdot\text{hunger}_j +$$

$$\boldsymbol{\beta_4} \text{ rural}\cdot\mathbf{X}_{ij} + \boldsymbol{\beta_5} \text{ nonrural}\cdot\mathbf{X}_{ij} + \boldsymbol{\beta_6} \text{ rural}\cdot\mathbf{X}\cdot\text{hunger}_{ij} + \boldsymbol{\beta_7} \text{ nonrural}\cdot\mathbf{X}\cdot\text{hunger}_{ij} + \mu_{0j} \quad (5)$$

Here the vector $\boldsymbol{X}_{ij}$ contains only the two individual-level factors age and education. Again, subtracting logit $\varphi 99_j$ from both sides of the two equations transforms the dependent variable to the odds ratio of a women being a farmer in 2003 vs. 1999/2000.

These models were estimated with the Restricted Iterative Generalized Least Squares (RIGLS) procedure employing penalized quasi likelihood (PQL) with a second order Taylor series approximation implemented in the MLwiN 2.02 software (Goldstein 2003, Rasbash et al. 2005). I also used Monte Carlo Markov Chain (MCMC) simulation which yields less biased parameter estimates in some situations, employing the WinBUGS program (Spiegelhalter et al. 2000) together with the interface in MLwiN (Browne 2003).

Equations 1-4 were also expressed using a log probability link function, with $\log \pi 03_{ij}$ and $\log \varphi 03_{ij}$ as dependent variables; on correcting for the site average log probability of being seropositive or being a farmer in 1999/2000, these become the log risk ratio of infection and the log risk ratio of being a farmer in 2003 relative to 1999/2000[2]. These equations were estimated assuming a negative binomial distribution of individual-level errors, employing RIGLS and 2nd order PQL in MLWiN. Risk ratio is the measure of choice for summarizing the impact of exposure on risk (Greenland 1987) and is also more intuitive and broadly understood than the odds ratio. However, as is common with the log link, convergence could not be achieved with one of the equations (equation 4), making it necessary to simplify the model. I therefore report the detailed analytical results from the logit link RIGLS analysis but present the key results from the log link analysis in graphic form, noting any substantive differences among the methods and estimation procedures in the text.

Results

HIV prevalence increased 20.2% over the course of the food crisis at rural surveillance sites; in contrast, prevalence declined 19.3% at non-rural sites (21.7% and 14.8% at semi-urban and urban sites, respectively; Table 1). The prevalence ratio was non-linearly related to the extent of rural hunger in the district at the rural sentinel sites, implying no increase in prevalence below a threshold of about 30% and a steep increase thereafter (model 1, Table 2 and Figure

[2] The risk ratio is also referred to as the prevalence ratio and is simply the ratio of the prevalence in the two years.

2). At the non-rural sites, the prevalence ratio was negatively related to rural hunger with no evident non-linearity; urban and semi-urban sites appear to have followed a similar pattern. This regression excludes one extreme outlier, the semi-urban site Nsanje (departure from predicted $p<.001$); I return to this case below. At the rural and non-rural sites where hunger was greatest, model 1 estimates HIV prevalence increased 142% and declined 49%, respectively.

[Table 2 and Figure 2]

Greater insight is provided by Model 2. The main effect coefficients indicate that, relative to the 1999-2000 mean, women who farmed or whose partners farmed were at reduced risk of being seropositive compared to non-farmers but the difference was only significant at the non-rural sites. Similarly, women with a secondary or higher education were more likely to be seropositive than were women with less than primary education only at the non-rural sites. Women under 25 years were significantly less likely to be infected than women older than 25 at both rural and non-rural sites. These results are very close to those obtained for the probability of infection in 2003 (equation 3, not reported) and are similar to the findings of other studies in Malawi. The excess risk for non-farmers and for better educated women had both diminished over time before the food crisis (Crampin et al. 2003, Dallabetta cited in Crampin et al. 2003).

There are no significant interactions at the rural sites and the coefficients for the effects of hunger at site level are little changed by the addition of the individual-level factors and the interactions. However, at the non-rural sites, the risk of infection for farmers declined significantly relative to the 1999/2000 mean: the log odds ratio fell 0.044 per unit increase in hunger compared to a non-significant 0.018 for non-farmers, controlling for woman-level factors and other interactions.

The results at the rural sites are consistent with a broad increase in the per capita risk of infection as hunger rose beyond the threshold that was not concentrated in any particular group. This could have been produced, as was reported at the time, by women becoming increasingly involved in situations where they were at heightened risk of exposure to HIV such as survival sex, less so by more frequent early marriage whose effects would have been concentrated in the under 25 year age class. Factors that increased women’s likelihood of becoming infected once exposed could also have contributed.

The negative association between the change in prevalence and rural hunger at the non-rural sites and the concentration of this effect in farmers is consistent with selective out-migration by farming women from rural areas. Evidence was cited earlier that the decline in livelihoods and the effect of the price spike were most keenly felt by those dependent on farming; also that migration in search of food or work was common. Women who moved to urban and semi-urban areas and who remained there long enough to become pregnant (if they weren’t already when they moved) and attend antenatal clinics there would have contributed to a reduced prevalence because they came from a lower risk environment: in 1999/2000, the probability of a farming women being HIV-positive at the rural sites was 10.6% (95% CI 6.2% - 17.5%) but 22.0% (19.5% - 24.8%) at the non-rural sites. Migrants would have diluted non-rural prevalence and the dilution would have been greater the higher the level of hunger-induced migration. As discussed below, this effect is likely to diminish with time.

The discrepant result for Nsanje in Figure 2B can perhaps be understood in this light. In 2005, a one-off surveillance site was established at a rural health centre in the district. Prevalence was 40.5% (95% CI 28.6% - 52.4%), higher than at the district hospital in 1999/2000 (26.0%, 95% CI 21.7% - 30.3%) or 2003 (33.0%, 95% CI 28.8% - 37.2%), indeed the highest level ever recorded at an antenatal surveillance site in Malawi. If similar infection rates prevailed in rural areas of the district during the famine, migration from the villages would, as observed, have raised rather than lowered prevalence in the town. I consider below what may lie behind this extraordinarily high rural prevalence.

If selective migration of farming women is responsible for the negative association between the change in HIV prevalence and rural hunger at the non-rural sites, then its effects should be visible in the demography of rural and non-rural areas. This hypothesis can be tested by analysing the changing composition of the women attending the antenatal clinics.

Model 3 (Table 3) indicates a significant linear relationship between the change over the course of the food crisis in the proportion of farmers attending an antenatal clinic and the extent of rural hunger in the district. Again, the direction of the relationship differs between rural and non-rural sites: negative at the former, positive at the latter. This is consistent with the selective migration of farmers from villages to towns and cities in response to hunger: the greater the movement of farmers out of the villages and into the towns and cities, the lower the proportion of farmers at rural antenatal sites and the larger the proportion of farmers at the non-rural sites (Figure 3)[3].

[Table 3 and Figure 3]

Figure 3A and Model 3 indicate that at rural surveillance sites where hunger was relatively low, the proportion of farmers in 2003 was greater than in 1999/2000 (ratio > 1). This is consistent with the accounts of rural people migrating to other rural as well as urban areas in search of food and work: districts with relatively low levels of hunger would have been the most attractive. A similar movement might also in part account for the fact that at non-rural sites where hunger in the surrounding rural areas was low the proportion of farmers in 2003 was less than in 1999/2000 (ratio < 1; Figure 3B and Model 3): some of the women farmers resident in or near those towns may have left them for the villages. However, this is unlikely a sufficient explanation because even at the highest levels of rural hunger the observed and predicted proportion of farmers in 2003 is not much more than that in 1999/2000. Although other explanations are possible (e.g. changes in the way occupation was recorded at the non-rural sites), the simplest and most consistent is that, for many of the women involved, leaving their villages was more than a temporary measure. A woman from a village attending an antenatal clinic in a town or city in 2003 who had decided to remain there would likely not give her occupation as “farmer”. In aggregate, such decisions would tend to depress the regression line. They would also lead to the overall decline in the proportion of farmers at non-rural, especially semi-urban sites evident in Table 1. I consider other evidence that bears on this below.

Model 4 (Table 3) provides more information about the characteristics of farmers and non-farmers and how this changed through the crisis. The individual-level main-effect coefficients

[3] The non-rural regression again excludes Nsanje although it is not a significant outlier in this case. Including it would little alter the results aside from increasing significance. The explanation suggested for Nsanje being an outlier in Figure 3 – greater HIV prevalence in the villages than in the town – would not be relevant to the movement of women *per se.*

indicate that at both rural and non-rural sites, relative to the 1999/2000 mean, farmers were significantly more likely than non-farmers to have less than a primary education and at rural sites to be less than 25 years of age.

The interaction coefficients indicate that at the rural sites, compared to the 1999/2000 mean, the proportion of farmers less than 25 years of age decreased significantly relative to older farmers as rural hunger in the district rose: the log odds ratio declined 0.194 per unit increase in rural hunger for the former and 0.126 for the latter, controlling for woman-level factors and other interactions. Note however, that both coefficients are significant. This suggests that farmers under 25 years had a greater propensity to migrate in response to hunger than older farmers who in turn had a greater propensity to migrate than non-farmers.

At the non-rural sites, compared to the 1999/2000 mean, the proportion of farmers with no formal education increased relative to farmers with a primary or secondary and higher education as rural hunger in the district rose: the log odds ratio increased 0.075 per unit increase in rural hunger for those with no education, 0.054 for those with primary education and 0.024 for those with secondary and higher education, again controlling for woman-level factors and other interactions. Only the first two are significant. This suggests a greater propensity to migrate in response to hunger in less educated farmers and especially those with no formal education than in those with secondary or higher education and in non-farmers.

These analyses suggest that women who left the villages were disproportionately young farmers while those who arrived in the towns and cities were disproportionately uneducated farmers. There is no contradiction because the comparisons are made to different populations, women attending the rural and non-rural antenatal clinics respectively, which differ in their composition. It should also be pointed out that the same statistical results would be observed had migration patterns been the inverse e.g. a selective migration of young non-farmers from towns and cities to villages in response to rural hunger. There no reason to believe there was such a movement but independent evidence is presented below that makes it possible to distinguish between these possibilities.

No substantive differences were found between the log probability and log odds forms of the four models and between the RIGLS and MCMC estimation procedures. As noted above, model 4 expressed in log probability form could only be estimated if simplified (education reduced to two categories: none and primary and above), but it suggested similar effects to the log odds form. The significance of the MCMC-derived regression coefficients at the site-level was lower than with RIGLS but the interpretation would be the same using either method. The significance of the individual-level and interaction effects was unchanged or in some cases enhanced using the MCMC procedure.

Data on migration from the 2004-05 Integrated Household Survey are presented in Figure 4. Across the country, 22.3% of women 15-24 years who were interviewed in towns and cities reported having moved to their place of residence from a rural area in the previous 3 years, roughly corresponding to the period since the beginning of the famine. Among women 25-49 years, the corresponding proportion was 11.8% (χ^2 =41.3, P<.01); in men 15-24 years and 25-49 years the proportions were 17.8% and 14.3%, respectively. Figure 4A also indicates that rural-to-non-rural migration in women 15-24 years peaked 1-2 years before the survey i.e. around the height of the food crisis in 2002-03. No such peak is evident in the other age-gender groups. The varying shape of these curves makes it less likely that some factor other than migration is responsible such as people recalling recent events better than more distant ones.

[Figure 4]

Figure 4B shows a similar pattern for rural-to-rural migration: greater in women 15-24 years than in women 25-49 years (20.4% vs. 9.6%, χ^2 =212.8, P<.01). In men 15-24 years and 25-49 years, the proportions were 12.3% and 12.4%, respectively. There is again a peak in migration 1-2 years before the survey that is most marked in women 15-24 years but also apparent in the other groups.

These results confirm the findings from the multilevel analysis of HIV prevalence and antenatal clinic composition: there is evidence of substantial migration from rural areas to both non-rural and other rural areas during the famine that involved women under 25 years of age significantly more than older women. Given that the IHS was conducted approximately a year after the 2003 antenatal surveillance round, the results also support the suggestion above that for many women migration was more than a temporary response to hunger. There is no support for an inverse migration of non-farmers from non-rural to rural areas that would have produced the same patterns: a very small percentage of rural women reported having relocated from non-rural areas in the three years before the survey (1.5% and 1.3% of 15-24 year old and 25-49 year old women, respectively).

Discussion

Taken together, the results suggest that the Malawi famine had a rapid and substantial impact on both HIV prevalence and demography across the country's rural and non-rural areas. The epidemiologic and demographic impacts are two sides of the same coin. How long these effects persisted cannot be assessed with the methods and data employed here although in the case of rural out-migration they were still apparent in the Integrated Household Survey conducted 1-2 years after the end of the famine[4]. The findings suggest that the impact of the famine has been deeper and wider than generally thought: its consequences must be assessed not just in terms of hunger and malnutrition but also in additional HIV infections, the bill for which will come due as these translate over the next years into illness and death or the lifelong costs of antiretroviral treatment, as well as in the dislocated lives left by widespread migration that was far from voluntary.

The findings indicate that in the rural areas where hunger was most extensive, HIV infection rates rose and that the increased infection risks were broadly shared across age, occupation and education classes. This is consistent with hunger leading women into an increased involvement in survival sex that raised their exposure to HIV and with hunger increasing the risk of infection once exposed due to depressed immune function. The reduced ability of rural women to insist on their partners using condoms may also have played a part although the level of use before the famine was relatively low: less than a quarter of rural women in 2000 reported having used a condom with their last non-cohabiting partner (NSO/ORC Macro 2001).

The implication of hunger-induced rural out-migration, disproportionately by farmers, in the decline of HIV prevalence at non-rural sites is supported by three lines of evidence: the

[4] The publication of the 2008 Malawi Census makes it possible to take this analysis further.

multilevel analyses of HIV prevalence change and of change in the composition of the antenatal population and the analysis of IHS migration data. The conclusion is in this sense more robust than the implication of hunger in the rise in rural prevalence. Nonetheless, one might ask whether this conclusion is plausible and whether the results are consistent: Does the amount of migration required to produce the observed reduction in non-rural HIV prevalence (model 2 and Figure 2B) correspond approximately to the observed extent of rural out-migration and non-rural in-migration (model 4 and Figure 3)?

A fuller treatment will be presented elsewhere; however, an initial assessment for Mchinji district and its antenatal clinic, the non-rural site where rural hunger and HIV prevalence decline were greatest, suggests the answer to both questions is yes. One needs to make several assumptions e.g. about the "catchment" from which migrants to the town originated, the proportion that in fact went to the town and the extent to which women who had been farmers gave their occupation as something else at the antenatal clinic. If the catchment was essentially the district and if most of its predicted 4,000 rural women migrants moved to the town they could well have produced the observed reduction in HIV prevalence and increased proportion of farmers at the surveillance site even if the proportion of women reporting a different occupation was large. A key factor is that the non-rural centres, especially the towns, have much smaller populations than the surrounding rural areas, giving the latter significant demographic "leverage".

It bears pointing out that catchment areas for migration are unlikely to have followed district boundaries. Particularly in the case of the cities, migrants may well have been attracted from a much larger distance. The analyses reported above used hunger in the surrounding district as the independent variable; however neighbouring districts that shared socio-economic and agronomic characteristics often had similar levels of hunger. As well, the methods employed give no indication of the frequency of transient migration: women who returned to their villages before the 2003 HIV surveillance round or the 2004-05 IHS.

I suggested earlier that the decline in non-rural HIV prevalence due to "dilution" by rural women migrating in distress was likely to have been an initial effect that reduced over time. The reason is that the women involved, predominantly young, farmers and with minimal formal education, were, before migrating, at relatively low risk of infection and at progressively greater risk as they settled in the towns and cities. Model (3) provides an indication of this increasing risk: a woman attending a rural antenatal clinic in 2003 who was a farmer, under 25 years of age and with less than a primary education had a 9.9% probability of being HIV positive. She had a probability of 12.9% if she attended a non-rural clinic and a 19.2% probability if her occupation changed to non-farmer, which appears to have been common. Migration nearly doubled her risk of infection, this suggests. But it is likely she would as well have been at increased risk compared to a non-migrant, non-rural woman with similar characteristics because social isolation added to poor education would have left her with few skills or resources to avoid situations of infection risk in the new environment. Whatever the extent of this additional risk, it seems evident that the famine gave rise to an increased burden of HIV infection not just among the women forced into survival sex in the villages but also among those forced into migration to towns and cities.

It is important to consider the relevance of these findings to situations beyond Malawi in 2001-03. Detailed data from neighbouring countries in this period are not available but a preliminary assessment for Zambia using aggregate data suggests a similar pattern of change in rural and non-rural HIV prevalence. Certainly, the underlying situations of risk were widely reported at the time in the region and are familiar in countries elsewhere, as the literature cited earlier indicates. In assessing the likelihood of other food access crises producing similar epidemiologic and demographic effects, at least two aspects of the Malawi situation appear to be critical. First, the shocks that triggered the famine in Malawi acted on a rural population whose livelihoods had become increasingly precarious; many had very few options left other than the most extreme. Second, hunger was very unequally experienced. This inequality was central to the operation of the main situations of infection risk: economic and social disparities within rural communities drove survival sex (a desperate seller, an able buyer); geographic disparities among rural areas and between them and non-rural areas drove distress migration.

The findings reported here are relevant to the "new variant famines" hypothesis developed and refined by Alex de Waal and colleagues (de Waal and Whiteside 2003, de Waal 2007). The hypothesis argues that HIV/AIDS persisting at high levels creates the potential for a new kind of crisis in food-insecure countries, marked by widespread death among mature adults, particularly women. Further, it suggests that "… there may be a vicious cycle in which poverty, migration and lower educational achievement in turn create greater susceptibility to HIV infection. This can then create a crisis of social reproduction. There are no data to support this conjecture" (de Waal 2007, p. 91). I believe this study has provided those data. Space does not permit pursuing these ideas here in the depth they deserve.

Finally, it is important to consider what light these results shed on non-famine situations, the seasons of chronic hunger which, for those affected, are probably indistinguishable from famine but which do not meet the conventional criteria for one. Taking the results (Models 1 and 2, Figure 2) at face value, as an indication of "dose-response", one would expect minimal increase in HIV prevalence in rural areas where less than the threshold of about 30% of households faced a significant food shortfall in the period before harvest and a decrease in non-rural prevalence approximately proportional to the percentage facing a shortfall. Caution is warranted, however. First, the non-linear rural relationship provides the best fit to the data but does not differ significantly from a positive, linear one: with only 8 rural sites, statistical power is limited. Second, the proportion of households that faced a shortfall in early 2003 – the extent of hunger – is only one aspect of the famine's severity. It does not convey the duration of the shortfall for those affected and it may only partly reflect the situation prevailing during the famine's first year. Third, the results integrate the impact of a large relief response, which, however partially and unevenly, likely reduced the famine's severity and the forces pushing people into extreme actions. Without it, larger effects would likely have ensued. Chronic, seasonal hunger has yet to compel the same level of response in alleviation or prevention.

Implications

Elsewhere, I take up a number of implications that are of particular interest to public health and epidemiology (Loevinsohn *submitted*). Here, I would like to focus on issues of interest to a wider audience, in particular how this new understanding of the role of hunger and its seasonal aspect should influence the conception of efforts aimed at preventing HIV and related diseases.

Poverty, hunger and inequalities are generally considered by public health professionals to be structural determinants of HIV infection and as such slow to change and essentially beyond the reach of near-term intervention in support of prevention. The findings indicate that these factors can in fact change rapidly and substantially in response to public actions, transmitting their effects to HIV prevalence with little lag. The actions highlighted here have been state actions and their impact has been baneful. These include the immediate ones in 2001-02 such as the liquidation of the SGR, the manner in which this was carried out and how food prices were set, as well as longer term ones that exacerbated seasonality and left people vulnerable to volatile food prices and even modest climatic variability.

Turning these findings on their head suggests opportunities. Not doing harm of the kind that provoked the Malawi famine, avoiding actions that unwittingly undermine food and livelihood security, is the most obvious one. More positively, efforts that bolster food and livelihood security broadly, across the year, could enable people to avoid situations of risk and escape infection. Indeed, successful such efforts may already be doing just that, yielding an as yet uncounted “prevention dividend”.

One place to look for clues as to what is feasible is in the left-hand sides of Figure 2A and B, the sites where hunger and change in HIV prevalence were lowest. The two most extreme sites from these graphs are in districts, Karonga and Nkhata Bay respectively, in the Northern Region. They share several characteristics but one that may be relevant to moderating the impact of famine and seasonal hunger is the widespread cultivation of cassava, grown by 71% and 83% of households respectively, according to IHS 2004 data. Cassava is a classic famine crop: more tolerant of drought than maize and less exigent in its labour requirements, it provides a large caloric yield per hectare.

Figure 5 suggests that cassava may be playing a moderating role not only in those two districts. The estimated extent of hunger in December 2002–March 2003, the independent variable in Figures 2 and 3, is now the dependent variable and the extent of cassava cultivation in these same districts the independent variable. Overall, there is a significant negative correlation ($r = -0.57$, $P<.01$): hunger was less prevalent where cassava was more widely grown. The relationship is closer when Southern Region districts and those with cities are excluded ($r = -0.85$, $P<.01$). Too much should not be made of this simple correlation based on aggregate data: one would want to see evidence that households growing cassava were more food secure than neighbours that did not. But cassava cultivation might also exercise a moderating effect in aggregate by reducing demand for grain and other foods, thereby damping the pressure on price – a benefit shared by all, whether or not they grow the crop. There is some evidence that this was happening during the famine. Figure 6 illustrates the relationship between the peak maize price in February 2002 in local markets (FEWSNET 2002) and the proportion of households growing cassava in the district. Again, the overall correlation is negative ($r = -0.63$, $P<.02$) – maize price was lower where more cassava was grown – but closer when Southern Region districts and peri-urban markets are excluded ($r = -0.81$, $P<.01$).

[Figures 5 and 6]

Clearly, these ideas require more detailed attention and more than a univariate analysis. Other crops likely play a similar role, notably sweet potato in the Southern Region. The historian Elias Mandala (2005) describes the reliance of farmers in Nsanje district on sweet potato and on production environments differentially affected by flood and drought in keeping famine at bay and mitigating seasonal hunger.

At this point, the evidence is suggestive that cassava cultivation provides an HIV “prevention dividend”, an unintended consequence of people’s struggle to secure food and livelihood.

Cassava is an important element of agricultural diversity and may be particularly helpful to poorer households caught in the dilemma of either working their own fields or doing *ganyu* in others: cassava is more forgiving of delay in planting, weeding and harvesting than maize. It is accessible and many appear to be reaching for it. There has been substantial growth in the area planted to cassava across the country and in neighbouring Zambia, even discounting some exaggerated and misleading official reports (Haggblade and Zulu 2003).

In some situations, where the hazards are clear, the "prevention dividend" may be very much in view and intended. In early 2003, at the height of the famine's second year, I heard a young woman in a village meeting in Zomba district in southern Malawi describe, with eyes cast down, how other women were being sent out at 4 PM to bring back a bowl of maize meal and, when they returned, no one asked how they had done it. She and other young women were requesting the village to let them use a patch of riverside *dimba* land to grow vegetables in the winter season which they intended to sell at a nearby teacher's college. They were also asking village leaders to intercede for them with a project of the Ministry of Agriculture and Irrigation that was distributing treadle pumps at subsidized prices to landed farmers, which the young women at that point were not. Innovation there was propelled by stark necessity but its success was not in the hands of those young women alone (Loevinsohn 2008).

Cassava is no panacea – malnutrition rates remain high in several of the Northern districts where it is widely grown – and, on its own, a small plot of out-of-season vegetables is unlikely to guarantee those young women the security they seek. The addition to food and income these innovations provide is useful, maybe critical, but limited. However, they can be built on. There are numerous ways to intensify vegetable production on small plots and to improve access to markets and market information. Likewise, there are opportunities to enhance the shelf life of cassava tubers and sweet potato and to add value and employment through processing. Local grain banks and related approaches can moderate the large swings in price between what people sell their produce for at harvest and what they buy it back for a few months later that are common in Malawi and other countries where markets are inefficient and post-harvest facilities underdeveloped. There is "a world full of good ideas" (Devereux et al. 2008). What is essential is that people's innovation be supported, particularly that of those too often marginalized – the young, women and the (near-) landless – allowing them to fashion progressively more robust livelihoods and to chip away at the structures that enforce seasonal hunger and health risk.

There is evidence that innovation in agriculture and natural resource management has in some cases enabled rural people to avoid seasonal situations of HIV infection risk as a consequence of having achieved greater food and livelihood security. One example is from India, where prevalence rates in some districts in the south and west are among the highest outside Africa. In these semi-arid, erosion-prone areas, watershed development (WSD) has sought to improve and harmonize the management of soil, water, pasture and livestock resources in order to sustainably increase crop and livestock production. Well over $500 million are now invested annually in WSD programs by the central and state governments. The initial preoccupation with physical outputs – check dams constructed, tons of rice produced – has in recent years been balanced by social concerns such as ensuring an equitable distribution of benefits and fostering responsive local institutions. Where programs have succeeded in striking that balance and ensured productivity gains are broadly shared – by no means always the case – a frequent consequence has been a marked reduction in distress-linked seasonal migration. This is a situation of HIV infection risk in India as in Africa.

A recent study assessed the impact of WSD on HIV's dynamics using an epidemiological model and demographic and health parameters from northern Karnataka state (Loevinsohn 2006). It concluded that through its effect on seasonal migration alone, WSD may currently be making a significant but entirely inadvertent contribution to the prevention of HIV, in some situations at a cost per infection averted comparable to condom promotion. This is in addition to its effects on other less visible situations of risk such as survival sex and on other health conditions, including several sexually transmitted infections, low birth weight and child malnutrition that share with HIV part of the causal pathways that link them with hunger.

It is important that these ideas are tested and that the reality of the prevention dividend is demonstrated. For many at the grass roots, much of this would seem self-evident: food underpins health and health enables one to produce or procure food. But it is important to bring these links clearly into focus for those devising policies and implementing programs in rural development and public health. A more conscious pursuit of the prevention dividend would make it possible to capture a number of synergies between the efforts of these two sectors. These exist in priority setting and targeting at the geographic level and in coordinated implementation of programs on the ground where health promotion and education can build on skills and local institutions that food and livelihood security efforts have fostered (Loevinsohn 2006).

The prospective benefit for HIV control from such coordination is more effective prevention, rendering less common situations where people understand the infection risks they face but, for economic reasons, cannot avoid them – the kind of situation the young women in Zomba district were struggling to escape. On the other side, the prospective benefit may be to add an element of self-interest to the moral imperative to reduce chronic, seasonal hunger. In the past, failure to do so has had a silent cost that has proven too easy to ignore. HIV now threatens, through social disruption and migration, to make the consequences substantially more audible and immediate.

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Table 1. Characteristics of the women surveyed at antenatal surveillance sites and of the surrounding district.

	Rural (n=8)		**Non-rural (n=10)**			
			Semi-urban (n=7)		**Urban (n=3)**	
	1999	**2003**	**1999**	**2003**	**1999**	**2003**
Number of women	1144	1627	3392	3618	1901	2460
HIV serostatus						
positive	12·1 (2·4)	14.5 (2.1)	27.6 (2.0)	21.6 (2.3)	25.6 (1.4)	21.8 (3.1)
Age						
15-19 yrs	24.9 (3.1)	22.0 (2.4)	24.0 (1.7)	20.7 (0.7)	20.0 (1.6)	19.7 (0.6)
20-24 yrs	38.9 (3.1)	36.2 (1.0)	39.5 (1.0)	40.3 (1.6)	43.2 (2.3)	44.1 (1.2)
25-44 yrs	36.2 (2.6)	41.8 (2.2)	36.5 (1.8)	39.1 (2.1)	36.8 (2.3)	36.2 (1.8)
Education						
None	23.6 (4.7)	29.8 (6.7)	29.1 (7.6)	31.7 (10.7)	8.8 (2.7)	10.2 (3.2)
Primary	70.6 (3.8)	64.6 (6.6)	58.6 (6.2)	54.8 (8.3)	62.4 (5.8)	63.9 (1.6)
Secondary +	5.8 (1.1)	5.7 (0.9)	12.3 (1.6)	13.4 (2.6)	28.8 (6.3)	25.9 (3.5)
Occupation						
Farmer	76.9 (5.1)	77.2 (4.6)	46.5 (3.5)	40.7 (6.3)	5.9 (4.3)	5.7 (2.9)
Non-farmer	23.1 (5.1)	22.8 (4.6)	53.5 (3.5)	59.3 (6.3)	94.1 (4.3)	94.3 (2.9)
Surrounding district						
Rural population in need of food assistance Dec 2002-March 2003	32.6 (3.8)		26.0 (4.3)		20.8 (3.8)	

Percent (se)

Table 2. Multilevel analysis of change in HIV prevalence at antenatal sites over the course of the famine. The dependent variable is the log of the odds ratio of a woman being seropositive in 2003 versus 1999/2000. Coefficients (95% C.I.)

	Model 1		**Model 2**	
	Rural	Non-rural	Rural	Non-rural
Site level				
Rural hunger				
Linear	-0.251 (-0.514, 0.013) +	-0.029 (-0.047, -0.012)**	-0.293 (-0.610, 0.023)+	-0.018 (-0.050, 0.014)
Quadratic	0.004 (0.000, 0.008)* †	–	0.005 (0.000, 0.009)*	–
Rural (dummy)	0.600 (0.296, 0.905) **	–	0.814 (0.122, 1.506)*	
Individual level				
Occupation				
Farmer			-0.235 (-0.690, 0.220)	-0.422 (-0.609, -0.235)**
Non-farmer (ref.)			0	0
Age				
< 25 yrs			-0.403 (-0.745, -0.060)*	-0.282 (-0.427, -0.138)**
25 + yrs (ref.)			0	0
Education				
None (ref.)			0	0
Primary			-0.002 (-0.454, 0.450)	0.012 (-0.189, 0.213)
Secondary +			-0.166 (-0.986, 0.655)	0.307 (0.064, 0.549)*
Interaction				
Occupation x rural hunger				
Farmer			0.002 (-0.066, 0.070)	-0.026 (-0.050, -0.002)*
Non-farmer (ref.)			0	0
Age x rural hunger				
< 25 yrs			-0.010 (-0.057, 0.038)	0.006 (-0.012, 0.024)
25+ yrs (ref.)			0	0
Education x rural hunger				
None			0	0
Primary			0.035 (-0.027, 0.097)	-0.002 (-0.030, 0.025)
Secondary +			0.043 (-0.069, 0.155)	0.004 (-0.029, 0.036)
Intercept	-0.396 (-0.531, -0.261) **		-0.156 (-0.392, 0.081)	
Between site variance (s.e.)	0.031(0.017)		0.048 (0.024)	

+ P<.10 * P<.05 ** P<.01 † Joint probability linear and quadratic <.05

Table 3. Multilevel analysis of change in the proportion of farmers at antenatal sites over the course of the famine. The dependent variable is the log of the odds ratio of a woman being a farmer in 2003 versus1999/2000. Coefficients (95% C.I.)

	Model 3		Model 4	
	Rural	Non-rural	Rural	Non-rural
Site level				
Rural hunger	-0.122 (-0.181, -0.063)*	0.053 (0.011, 0.095)*	-0.126 (-0.217, -0.036)**	0.075 (0.024, 0.126)**
Rural (dummy)	0.767 (0.190, 1.345)**	–	0.972 (0.162, 1.782)*	–
Individual level				
Age				
< 25 yrs			0.497 (0.094, 0.899)*	-0.014 (-0.173, 0.144)
25+ yrs (ref.)			0	0
Education				
None (ref.)			0	0
Primary			-0.838 (-1.430, -0.246)**	-0.150 (-0.373, 0.073)
Secondary +			-1.678 (-2.555, -0.802)**	-1.205 (-1.511, -0.899)**
Interaction				
Age x rural hunger				
< 25 yrs			-0.068 (-0.122, -0.014)*	-0.003 (-0.024, 0.019)
25+ yrs (ref.)			0	0
Education x rural hunger				
None (ref.)			0	0
Primary			0.044 (-0.033, 0.121)	-0.021 (-0.054, 0.011)
Secondary +			0.025 (-0.086, 0.136)	-0.051 (-0.092, -0.011)*
Intercept	-0.169 (-0.497, 0.159)		0.096 (-0.282, 0.474)	
Between site variance (se)	0.227 (0.088)		0.225 (0.088)	

* P<.05 ** P<.01

Figure 1 Prevalence of HIV in women attending antenatal clinics in Malawi 1994-2005. Data courtesy National AIDS Commission.

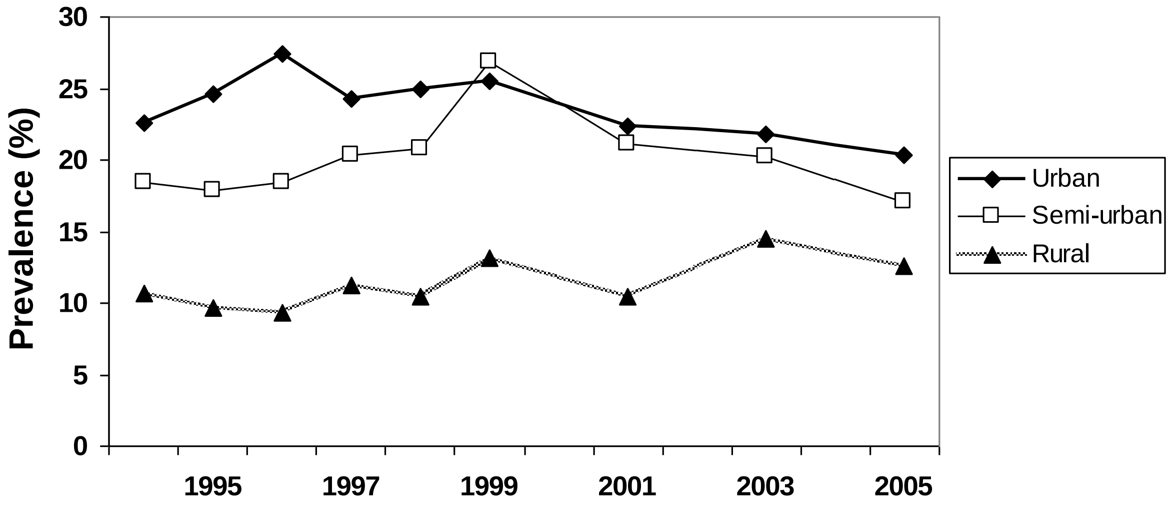
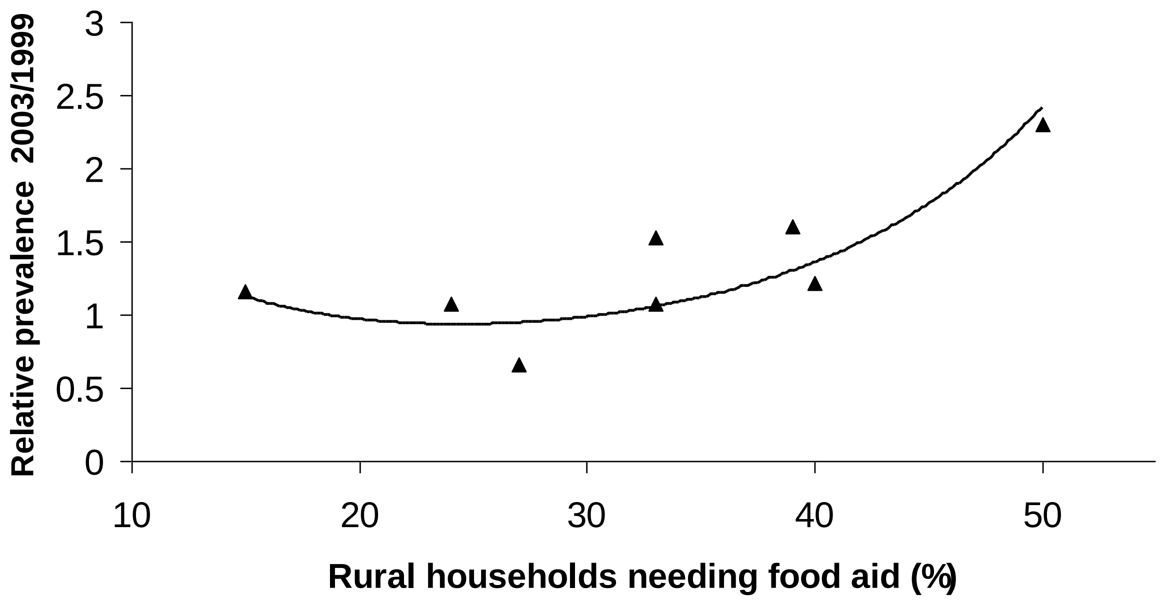


Figure 2 Change in HIV prevalence at antenatal sites over the course of the famine in relation to the proportion of rural households estimated to be in need of food assistance in the surrounding district in December 2002-March 2003. A. Rural sites; B. Non-rural sites (triangles: towns; squares: cities). The outlier (Nsanje) is not included in the analysis (see text).

A



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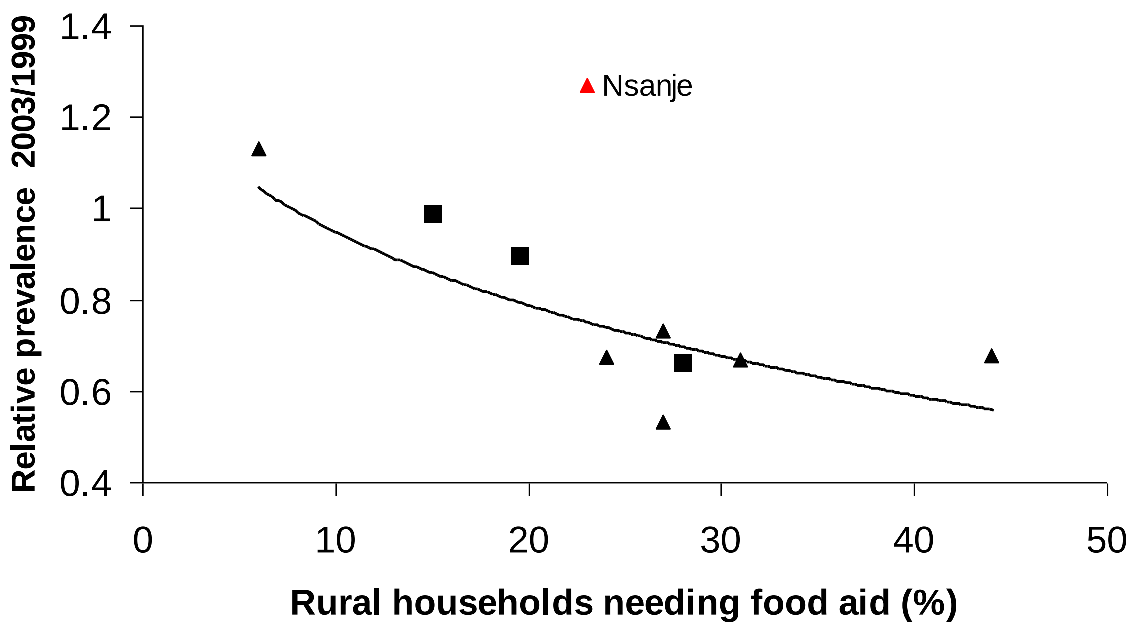
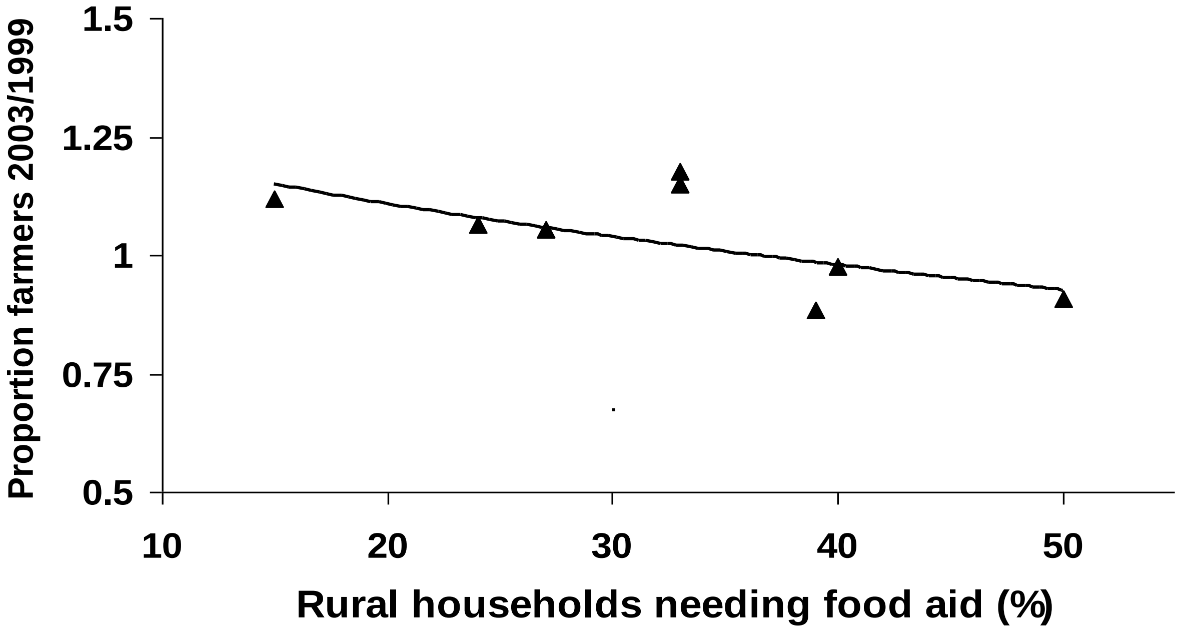


Figure 3 Change in the proportion of farmers at antenatal sites over the course of the famine in relation to the proportion of rural households estimated to be in need of food assistance in the surrounding district in December 2002-March 2003. A. Rural sites; B. Non-rural sites (triangles: towns; squares: cities). The outlier from Fig. 2 (Nsanje, open triangle) is not included in the analysis (see text).

A



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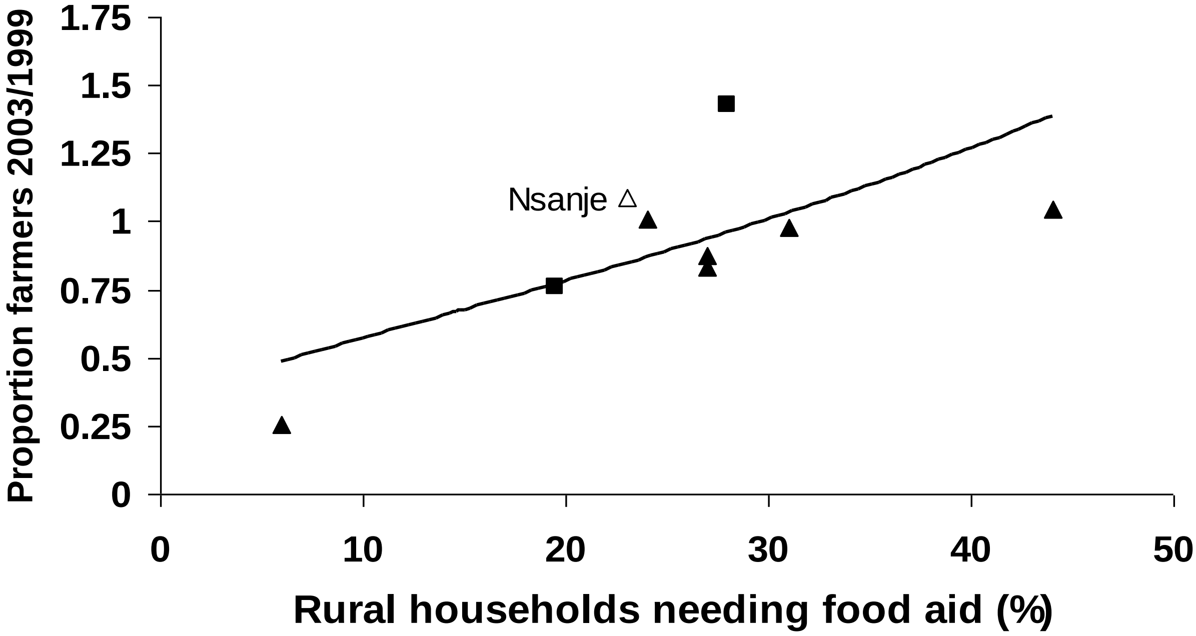
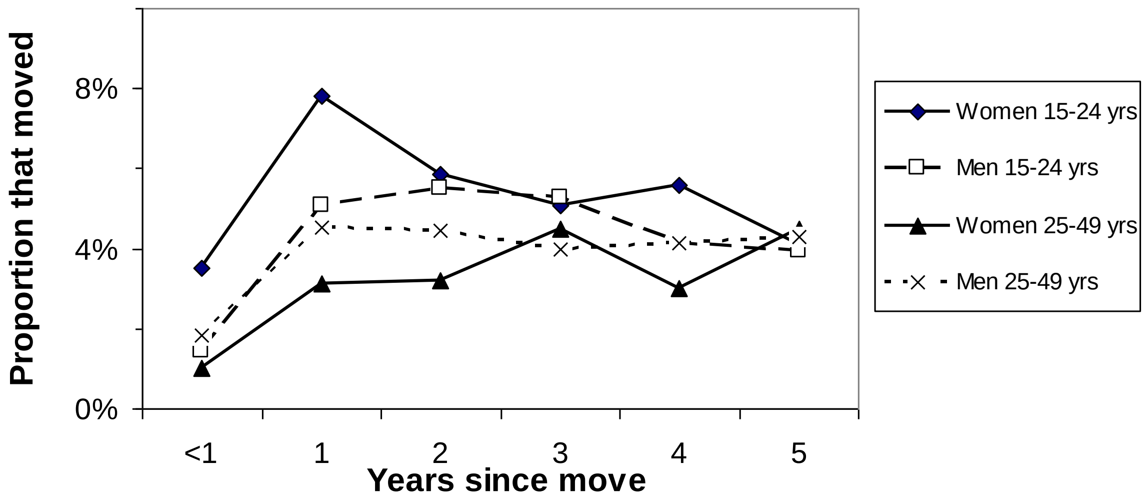


Figure 4 Prevalence of migration in Malawi, assessed in 2004 and early 2005. A. Rural to non-rural migration. Non-rural includes cities, towns and the district *bomas* (administrative centres). N=4,427. B. Rural-to-rural migration. N=17,722.

A.



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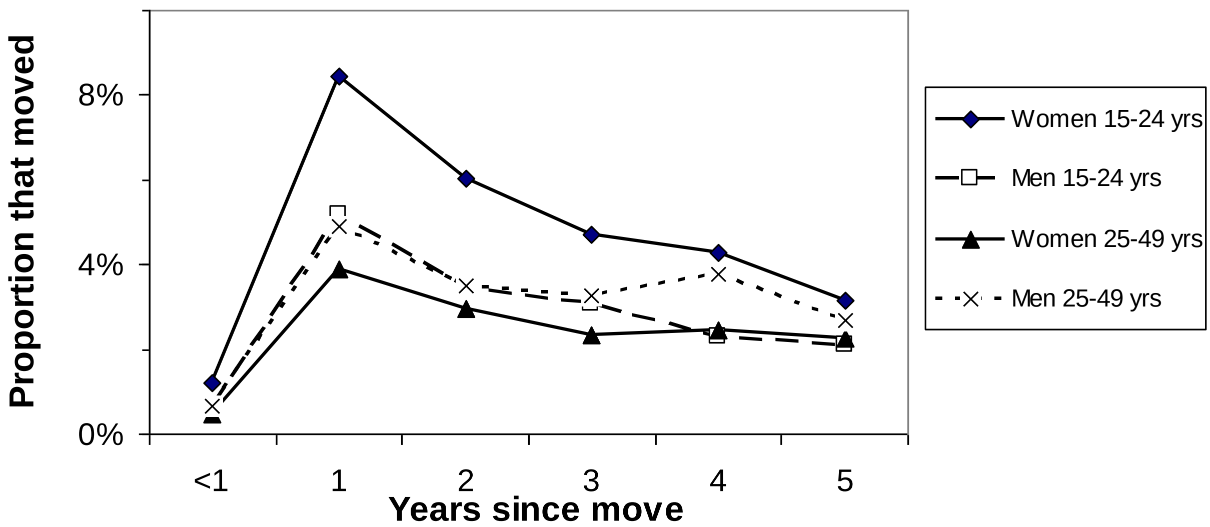

Figure 5. Proportion of households estimated to be in need of food assistance in December 2002-March 2003 in relation to the proportion of households growing cassava, by district. All districts, with and without antenatal surveillance sites are plotted (n=26); the regression is fitted to the non-peri-urban Northern and Central Region districts (n=13).

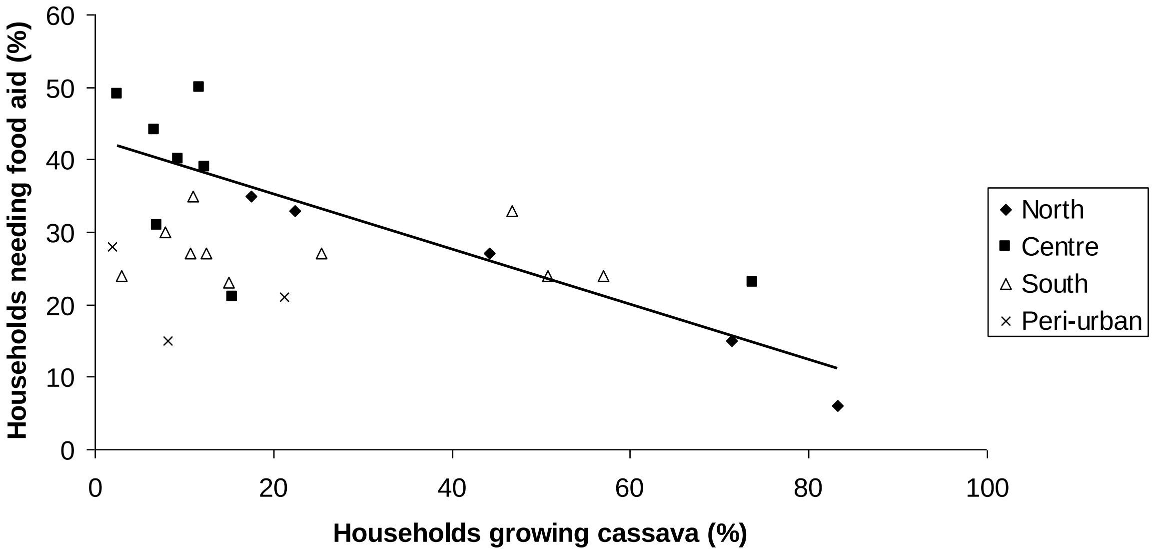

Figure 6. Peak maize price in February 2002 in local markets (Malawi Kwatcha) in relation to the proportion of households growing cassava in the district. All districts reporting market prices are plotted (n=15); the regression is fitted to the non-peri-urban Northern and Central Region districts (n=9).