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The Impact of Fertilizer Tree Systems in western Kenya

A study on Impacts of Agroforestry

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The impact of fertilizer tree systems in western Kenya

by Frank Place, Michelle Adato, Paul Hebinck, Maggie Lwayo, Mary Omosa, Mary Nyasimi, Christopher O'Leary, Wesley Ongadi, Eward Ontita, and Pamella Opiyo[1]

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[1] Much of this report is from 'The Impact of Agroforestry-Based Soil Fertility Replenishment Practices on the Poor in Western Kenya' by Frank Place, Michelle Adato, Paul Hebinck, Maggie Lwayo, Mary Omosa, Mary Nyasimi, Christopher M.C.O'Leary, Wesley Ongadi, Edward Ontita, Pamella Opiyo, IFPRI Research Report 141, Washington, DC.

1. Introduction

Much of western Kenya is considered to have good potential for agriculture, with medium elevation (1100 – 1600 metres above sea level), deep, well drained soils, and relatively high rainfall (1200 – 1800 millimetres per year) that permits two growing seasons. Indeed, the region has the potential to be one of the most productive agricultural regions in all of Africa. Unfortunately, this is not the case. Farming is mainly low input – low output farming, practised on small farms of less than 1 ha, due to a burgeoning population. As a result, there are more people below the poverty line per square kilometre in the western Kenya region than anywhere else in Kenya. Indeed, national statistics show that over 50% of the population in many of the districts in western Kenya lives below the poverty line of 1240 KES per adult per month (equal to about USD 16).

Why is this? Recent studies have found that crop productivity is very low. The typical output from a 'good' rainy season is less than 1 tonne of maize per hectare, although the potential is for 5 or 6 tonnes. However, farmers are poor and cannot afford to purchase fertilizer at nearly the needed amounts. Thus, as each year passes, soils become more and more depleted of nutrients. In response, ICRAF, KARI, and KEFRI[2] developed an agroforestry research programme that had as one of its pillars, systems to improve welfare through soil fertility replenishment. Some successes with farmers were achieved in the mid-1990s and an effort to scale up the successful agroforestry systems was launched in 1997. This paper summarizes the research to document the adoption and impact of these systems since that time. The research involved is diverse, using a range of quantitative and qualitative methods and combining researcher managed trials and surveys of farmers' own experiences.

Section 2 describes the main fertilizer tree systems developed and disseminated and how they are envisaged to work. Section 3 provides a brief contextual background for the study areas, including an overview of people's agricultural resources and practices. Section 4 describes patterns of farmer adoption of the technologies. Section 5 presents quantitative and qualitative evidence on the impacts of the fertilizer tree systems on yields, production, income and assets.

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[2] ICRAF is the International Centre for Research in Agroforestry, KARI is the Kenya Agricultural Research Institute, and KEFRI is the Kenya Forestry Research Institute.

Section 6 analyzes the effectiveness of different dissemination approaches used in western Kenya. Lastly, there is a brief summary and conclusion.

2. The soil fertility replenishment technologies

Initially, several systems were tested, including alley farming, but the two that appeared to be most promising, were improved fallows and biomass transfer using fertilizer trees. For the remainder of this paper we will refer to the systems as fertilizer tree fallow and fertilizer tree transfer systems. A third promising system, a fertilizer tree intercrop, has recently been tested in western Kenya but has yet to be widely tested by farmers. A fertilizer tree fallow is a fallow of at least one growing season in which an appropriate tree species is planted. Fertilizer tree fallows are more efficient than natural fallows and can normally have the same effect on crop productivity in a much shorter time. They are planted and left for fallow for one season, normally the short rainy season (October – December), after having been planted towards the end of the long rainy season (that is April/May). Farmers then plant their crop (normally maize) during the following long rainy season and may continue to cultivate the crop for more seasons, using the residual fertility effect from the fallows.

Many fertilizer tree species are being used by farmers. The two main fallow species being used by farmers in fertilizer tree fallows are *Crotalaria* spp. (see photo 1), *Tephrosia* spp., and *Sesbania sesban*. They are shrub species that develop a good canopy and a sizeable leaf biomass in a short period of time and both fix nitrogen from the atmosphere.. More recently, a small number of farmers are testing a permanent intercrop using *Gliricidia sepium,* a coppicing species (that is one that regrows following cutting). For the species that are directly seeded (all but *Sesbania sesban),* the seeding rate is very dense at up to 26 000 plants per hectare, thus forming a closed canopy very quickly. Farmers mainly plant by simple broadcasting of the seed. For *Sesbania sesban,* farmers germinate the seeds in a nursery and transplant them bare-rooted into the fields. At the time of land preparation, the trees are cut down. The leaves and small twigs are incorporated into the soil and the larger branches and stems are kept aside for other uses. The planting and cutting of fallows requires additional labour (see section 5 below), but there are also some savings due to weed reduction and soil improvement.

Photo 1: A *Crotalaria grahamian*a fertilizer tree fallow

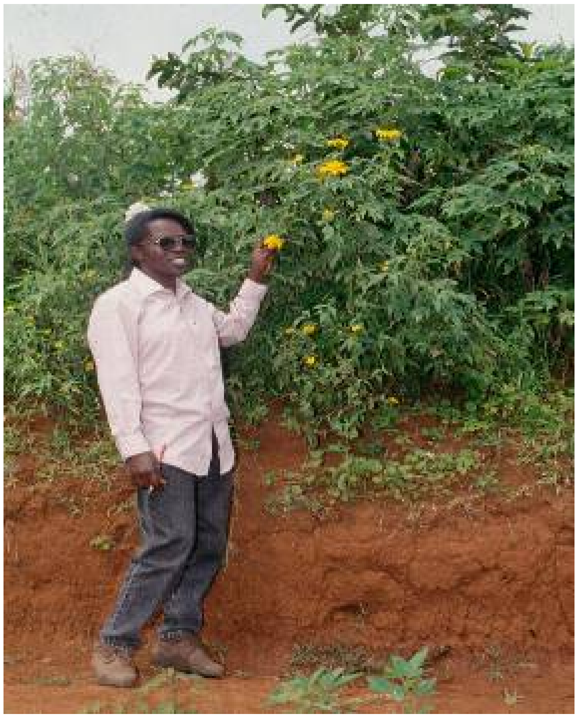


Photo 2: A hedge of *Tithonia diversifolia* for biomass transfer

Fertilizer tree biomass transfer systems are those where organic nutrient sources are grown in one place and then transferred to crops in another place. The most popular shrub species used in transfer systems is *Tithonia diversifolia* (see photo 2). This species was selected among many locally found species because it is a prolific grower (found throughout the region), is easy to establish and work with, and its leaves contain high concentrations of nutrients, especially nitrogen. Farmers gather the leaves from off-farm or plant the shrub on boundaries or contours on their own farms. They then incorporate the leaves into the soil at planting and sometimes use new leaf growth as mulch later in the season. This system allows farmers to grow crops continuously, which is an advantage over a fallow system, but the available space for producing organic nutrient sources on-farm is limited. As a result, farmers are using biomass transfer systems significantly and increasingly on small plots containing high value crops such as kales and tomatoes, rather than maize.

A third system is one in which a coppicing tree species (one that grows back when its stem is cut) such as *Gliricidia sepium* is grown as a permanent intercrop with maize. The advantage of this system is that farmers do not lose a season of maize production and therefore it is more attractive than a rotational fallow for farmers with small landholdings. This has proven successful in southern Malawi, but its testing and promotion in Kenya was introduced too recently to evaluate at the time of this synthesis.

3. Agriculture in the region

The study area spans two major ethnic groups in western Kenya, the Luo and Luhya communities. There are some differences in customs and agricultural practices between the two groups when considering the wide areas the two inhabit. However, in the highland area of Siaya and Vihiga, the agricultural production systems of the two are quite similar. Thus, this section paints a general picture that is applicable to both groups. Where significant differences are found, these will be noted in the relevant section.

Generally, rural households pursue and combine several livelihood strategies, both on- and off-farm. In Siaya and Vihiga Districts of western Kenya, most households pursued at least one of the following sources of livelihood: rainfed farming, livestock rearing, business, employment, and remittances from family members. The large majority of time is spent on farming. Females are slightly more likely than males to be farmers. Males, on the other hand, are more likely than females to have non-agricultural casual jobs. Full-time work off-farm is an important livelihood for about a third of all households. Casual labour, while common, is not often a major livelihood source and remittances and pensions are important in size for just a few households. For those that rely on agriculture as a source of livelihood, maize and bean production dominates throughout. Among the ‘higher value’ crops, vegetables are also important sources of livelihoods, but there are hardly any ‘industrial crops’ such as tea, coffee, or sugarcane grown in these villages. It must be emphasized that there are different types of farmers and farming systems and these are not static, but have changed over time. The set of livelihood strategies pursued and the importance of any given one may also change over time. Hence, in spite of investments already made in terms of farming knowledge and skills, some farmers easily shift their focus away from farming on their own land.

Among the issues that therefore emerge as central to this impact assessment is the need to understand the driving forces behind the choices that people make and why they sometimes remain in strategies that seem unprofitable. Intentions to invest in more attractive opportunities are easily thwarted by lack of resources or keen competition for them. Therefore, whereas the rural poor may be in a position to appreciate the dynamic changes around them, they are often unable to take full advantage of opportunities that are perceived as capable of uplifting their welfare. Also, almost all the people tend to want to do that which is commonly undertaken in their home area to feel part of the community. For example, the relatively progressive farmers may still produce some low-value maize to prevent any accusations that they steal the maize of others.

Even where households have managed to engage in more productive activities, a variety of shocks can occur which cause them to rapidly fall back. The most common and serious are human illnesses. HIV/AIDS is widespread in the region where it is estimated that 22% and 12% of the 15-49 year old population was infected in Nyanza and Western Provinces respectively (Ministry of Health 2001). Malaria is also common and the costs incurred and labour time lost due to these diseases is huge. Traditional funerals consume considerable time and resources. Farmers also face risks associated with climate – dry periods, heavy rains, and hail – with little ability to cope with or insure against them. Lastly, there are large economic risks associated with markets: availability of inputs is not assured and prices for outputs vary widely during the year and are often low when farmers are likely to sell (at harvest) and high when they are likely to buy (just before harvest).

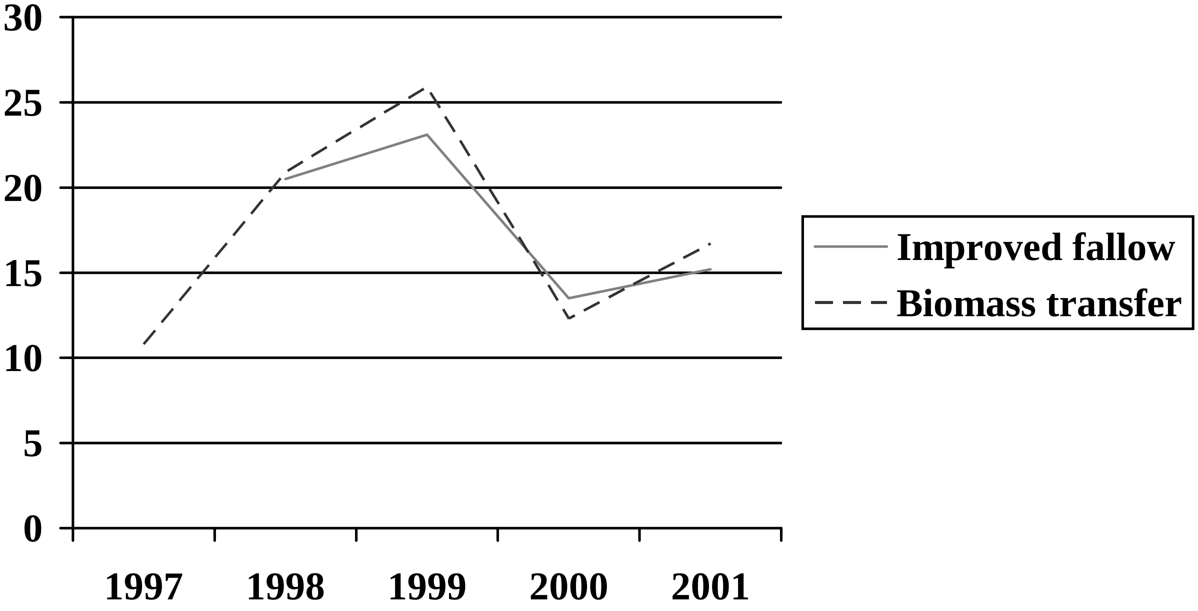
All these points show how complicated and difficult it is to catalyse and sustain processes for poverty reduction in an impoverished setting like western Kenya. Poverty is associated with lacking income both from employment and business. Poor people have small pieces of land, grass thatched houses, and large families with children walking in tattered clothes and who have fallen out of school. The main descriptors of poverty in the words of respondents are:

- lack of land
- no daughter or son on the farm
- inability to feed one’s family
- inability to pay for education, health care and so on
- wearing of tattered clothes
- having unemployed children
- being physically disabled
- housing with a leaking roof

4. Adoption of improved fallows and biomass transfer

There are distinctive patterns inside and outside ICRAF’s pilot intervention area. Inside the pilot villages, there was a rapid surge of users between 1997 and 1999, where the user rates reached about one quarter of households for each technology (see figure 1). There was then a significant decline in use in 2000 followed by a slight recovery in 2001. In 2001, 15.2% of households were using improved fallows and 16.72% were using biomass transfer. A likely interpretation is that considerable technical support along with the bandwagon effect may have led to early high rates of testing. This was followed by discontinuation by those who did not receive sufficient benefits or were unable to manage the technology after ICRAF and partners reduced backstopping efforts.

Figure 1: Adoption patterns of improved fallows and biomass transfer in the pilot villages, by over time, 1997-2001 (percent of 1,630 households)

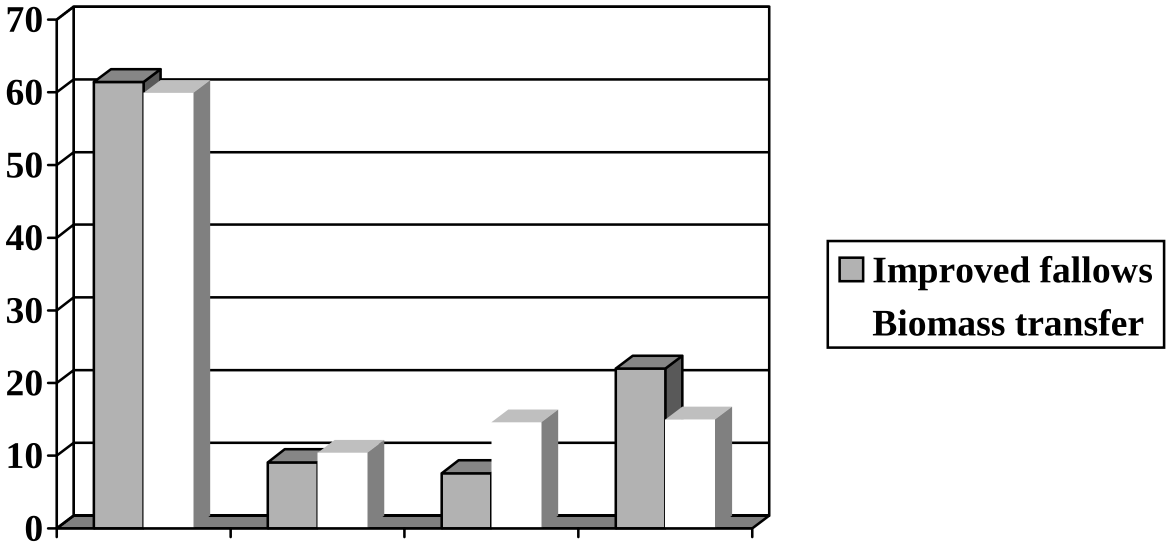


Finally, in early 2001 when the villages adjusted to being weaned from ICRAF support, some testers retried the systems and new testers emerged. Because of reasonably lengthy exposure to agroforestry within pilot villages, it is possible to classify households into different categories of adoption. The adoption dynamics for each technology were summarized into four mutually exclusive outcomes:

1. households that never used the technology (non-users)
2. households that used the technology early on but never again (dis-adopters)
3. households that did not use the technology early on but used it recently (recent testers)
4. households that used the technology at least twice including early and later years during the period (adopters)

As indicated in figure 2, the highest proportion of pilot village households had never tried either of the technologies as of 2001, about 60% in each case. A greater percentage of households have adopted improved fallows (22.0%) than biomass transfer (15.0%).[3] However, about twice as many households have recently tested biomass transfer than have tried improved fallows (14.6% compared to 7.6%). For each technology, about 10% of households tried and then dropped the practice. This may be due either to disappointment with the performance of the technology, or to the realization that the investment required is too much to bear, or happens because the farmer was initially using the technology for other purposes, such as to sell tree seed to ICRAF or to develop closer ties to external organizations

Figure 2: Adoption patterns of improved fallows and biomass transfer in the pilot villages by 2001 (percent of 1,630 households)



Outside the pilot villages, censuses were conducted for six different sites (about 1000 households in all). Because the rates of use are expected to be relatively high compared to other non-pilot villages (indeed, this is one of the reasons these villages were selected), these should not be taken to be representative of dissemination success. Rates of use are very high in five of the six sites, with rates ranging from about 24% to 59%. This is encouraging, given that technical support from the project in these sites has been relatively low.

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[3] The percentage of adopters of improved fallows is greater than the percentage planting fallows in 2001 because some adopters may have planted in the year 2000 and not in 2001.

The comparison of users of these new agroforestry techniques with users of more traditional techniques such as fertilizer and manure is interesting. Among farmers in the non-pilot villages who had not been using traditional soil fertility practices (which is about half of farmers), 44% were testing or using the agroforestry technologies. In the pilot villages, the same statistic is 30%. This shows that the agroforestry systems are in fact reaching a significant group of poor farmers who otherwise did not have access to other useful soil fertility management practices.

Average fallow area was highest in 1998, dropping to a low in 1999 and recovering somewhat in 2000 and 2001. Fallow size was reduced in 1999 partly due to lower rainfall and seed supply constraints and the fact that ICRAF began to divert some attention from the pilot areas in order to scale out information to other places. In 2001, the mean fallow size (among practitioners) was 440 m^2 or 0.04 ha. While this does not sound like much, it should be recognized that farm size for many is about 0.6 ha, of which perhaps 0.3 to 0.4 ha is under maize. Further, the fallow system calls for a rotation of a fallow followed by three seasons of maize. If this pattern is followed, one would expect only one fourth of the maize area to be under fallow at one time – this would be between 0.075 and 0.1 ha. Viewed in this way, adoption intensity among those using fallows appears to be quite high.

Planting *Tithonia* to provide the organic matter for biomass transfer systems is perceived as an increased investment in the biomass transfer system. It also reduces the subsequent labour required for collection of the material off-farm. Considerable planting occurred in 1998, 1999, and 2001, when over 11% of households planted in each year. Curiously, the percentage of households planting in 2000 was much lower (4.2%). Whether this is a sign of saturation or an anomaly is uncertain and will be monitored over time.

4.1 Adaptation and adoption of agroforestry systems

Customarily among the Luo and Luhya, it is the husband who makes important decisions, therefore also on whether or not to adopt the new agroforestry techniques. It is the case in our study sites that women have to ask their husbands' permission to attend seminars and meetings called by ICRAF and other agencies to disseminate information on fertilizer tree systems. This does not imply directly that women do not participate at all or that they have no say in such matters. In fact, in some of the households, women farmers took leadership in acquiring information about agroforestry and testing it on their farms. An interesting difference occurs at the level of pilot versus non-pilot villages. Women are active adopters of the new technologies in the pilot villages, but this was the opposite in the non-pilot villages, where men were more often mentioned as the main adopters.

At this point we can elaborate in more detail what kind of typology of agroforestry users is relevant. The '*seed adopter*' refers to those that recognized the opportunities that the seed market in the early start of the project offered to them. These types of 'adopters' were stimulated by the relative high prices seeds were fetching at the time, to grow the seeds that were collected by ICRAF. They were found primarily in the pilot research villages facilitated by ICRAF and most dropped out of seed provision as the prices for seeds went down and the seeds were not any longer collected by formal organizations. The '*NGO-networker*' stands for the individuals that through their early involvement with agroforestry and ICRAF managed to manoeuvre themselves into strategic positions to gain access to resources distributed by NGOs and other projects or programs. Their involvement with agroforestry in their capacity of village elder or secretary of a community committee made them known to other agencies. The '*keeners*' are those that perceive agroforestry as a good addition to the many ways to replenish soil fertility. They are keen on agroforestry as it increases yields and reduces monetary costs for maintaining soil fertility. The '*keeners'* represent the largest group of users by far, though there are believed to have been significant numbers of '*seed adopters'* and '*NGO-networkers'* too.

In both the pilot and non-pilot study areas, econometric regressions were used to examine the effect of several explanatory variables on the different classifications of adoption (or not) of improved fallows or biomass transfer (examined in separate models). The explanatory variables pertain mainly to household-level factors such as household structure and resource levels. The key results from several studies are summarized below. We include regression results from a large sample analysis of improved fallows and biomass transfer systems within the pilot villages (tables 1 and 2).

4.1.1 *Improved fallows*

Two surveys were conducted with farmers to assess management and innovation in the use of improved fallow and its feasibility and acceptability with farmers of different characteristics. The first survey in 1998 involved 140 farmers (DeWolf et al. 2000) and a second in 1999 involved 67 farmers (Pisanelli et al. 2000). From the larger survey, it was found that from a technical point of view, farmers had little trouble in establishing their fallows. Most (70%) did so in an existing crop to save on land preparation and weeding, although in 28% of these cases, farmers reported a negative effect on that season's maize crop, as they may have planted too early in the season. Labour and land constraints were also investigated. About one third of farmers said that land preparation after an improved fallow was more difficult than after a natural fallow (more felt otherwise). Only one farmer discontinued the use of the technology for this reason. The study by Pisanelli et al. (2000) found that 55% of the fallows were cut by women, 35% by men, and 10% by mixed groups, so improved fallows do not appear to be less acceptable to women for physical or cultural reasons.

Econometric analyses were also conducted on 1,600 households in the pilot villages and 360 households in non-pilot villages to see whether use or adoption of improved fallows was associated with any particular type of household characteristic. In the pilot villages (table 1), wealth was not related to use of the improved fallows, suggesting that the different use patterns are neutral with respect to wealth indices of households – the poor are as likely to be adopting as the wealthy. Household type was also not related to adopting improved fallows – the technology is being adopted by female-headed and other non-traditional household structures as frequently as by the more common male-headed monogamous household. However, among the early adopters, Pisanelli et al. (2000) found that women planted smaller areas to fallows than did men. A final variable linked to poverty[4] shows a different pattern. Non-adopters of fallows have smaller farm sizes than dis-adopters and adopters (though smaller farms tend to plant a higher proportion of their land to fallows, Pisanelli et al 2000). Somewhat encouraging is that households who are newly trying improved fallows tend to have farm sizes indistinguishable in size from non-adopters. Similarly, while early use was higher among Luos as compared to Luhyas, new testers are equally likely to be Luhyas as Luos. Finally, the technology was being used equally by the more or less educated.

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[4] Note that farm size is not always identified by rural households as a key criterion for wealth differentiation among households.

Table 1: Household factors related to adoption of improved fallow in the pilot villages 1997-2001 (n = 1,583)

	Outcome		
Variable	**Used early and dropped**	**Used recently only**	**Used throughout period**
Constant	-3.0833**	-2.7064**	-2.5034**
	(.0000)	(.0000)	(.0000)
Pilot village	.6555**	-.1494	.8041**
	(.0006)	(.4238)	(.0000)
Luo household	1.3505**	.2413	.9998**
	(.0000)	(.2714)	(.0000)
Number of adults	.2685**	.1331**	.0944**
	(.0000)	(.0189)	(.0214)
Female head – husband away	.6750**	.4922	.0461
	(.0318)	(.1336)	(.8414)
Female head – no husband	.1070	.3812	.0262
	(.6892)	(.1480)	(.9150)
Male head – polygamous or single	.6628**	-.3149	.1717
	(.0136)	(.4238)	(.4238)
Secondary education	-.8548**	-.2650	.2335
	(.0246)	(.4840)	(.3682)
Upper primary education	-.2314	-.1058	.1763
	(.4008)	(.7589)	(.4231)
Lower primary education	-.2194	.2804	-.0686
	(.4377)	(0.94)	(.7642)
Age	-.0168**	-.0055	-.0059
	(.0358)	(.5389)	(.3174)
Farm size	.1417**	.0846	.2306**
	(.0246)	(.2302)	(.0000)
Wealth index	.0418	.1270	.0395
	(.5828)	(.1216)	(.4840)
Percent of cases observed	9.1	7.6	22.0

*Notes: Omitted outcome is the group of farmers never trying improved fallow. P-values in parentheses; ** significant at least 5 percent level; * significant at between 5 and 10 percent level*

4.1.2 *Biomass Transfer*

For biomass transfer the results from the pilot villages are presented in table 2. The wealth index variable was again not related to adoption of biomass transfer compared to non-adopters; but it was positively related to use of the system in the non-pilot sites. Thus, the pro-poor nature of this technology is more mixed than the case of the improved fallow. The structure of household is not related at all to the pattern of use of biomass transfer so that the technology appears neutral with respect to household decision-making structures. However, an earlier study in just Vihiga District found that male headed households were more likely to continue using biomass transfer than were females (Obonyo 2000). The size of farm is positively related to the adoption of biomass transfer and so is the supply of labour. When the land-labour ratio is used as an explanatory variable (rather than the two variables independently), it is not significantly related to any of the outcomes, implying that neither land nor labour dominates as a constraint.

Education and age play a stronger role in use of biomass transfer than they do for improved fallows. Better-educated household heads are more likely to have adopted biomass transfer than uneducated. Similarly, there is some support that more education leads to less dis-adoption than non-adoption. Age of household head is not statistically related to adoption, but younger heads are more likely to be recent testers as well as being dis-adopters as compared to those who had never tried biomass transfer. So younger household heads seem to show great interest in biomass transfer, but have not always had sustained interest or perhaps the ability to maintain the use of the practice. Lastly, use of biomass transfer was found to be higher amongst the Luo relative to the Luhya.

Table 2 Household factors related to adoption of biomass transfer in the pilot villages, 1997-2001 (n = 1,583)

	Outcome		
Variable	**Used early and dropped**	**Used recently only**	**Used throughout period**
Constant	-1.765**	-1.9317**	-3.6500**
	(.0002)	(.0000)	(.0000)
Pilot village	-.1868	.4200**	.7082**
	(.2714)	(.0070)	(.0000)
Luo household	.1926	1.0225**	1.9524**
	(.3174)	(.0000)	(.0000)
Number of adults	.1019**	.1660**	.2045**
	(.0456)	(.0004)	(.0000)
Female head – husband away	-.0801	-.3833	-.1384
	(.7642)	(.1936)	(.6892)
Female head – no husband	-.0854	-.1599	.0303
	(.7644)	(.4840)	(.9204)
Male head – polygamous or single	.3162	.0911	-.0365
	(.2302)	(.6892)	(.9220)
Secondary education	-.3323	.0778	.7820**
	(.3174)	(7890)	(.0094)
Upper primary education	-.5478**	.0254	.5783**
	(.0456)	(.9204)	(.0214)
Lower primary education	-.2762	.0638	-.1561
	(.2714)	(.7895)	(.5486)
Age	-.0130*	-.0218**	-.0041
	(.0892)	(.0010)	(.5486)
Farm size	.0770	.0693	.1352**
	(.1336)	(.1616)	(.0026)
Wealth index	.2596**	.1679**	-.0172
	(..0004)	(.0070)	(.7889)
Percent of cases observed	10.4	14.6	15.0

*Notes: Omitted outcome is the group of farmers never trying biomass transfer. P-values in parentheses; ** significant at 5 percent level or less; * significant at between 5 and 10 percent levels.*

5. Impact on livelihoods

The major direct effect of fertilizer tree fallows is to increase the crop production environment leading to increased crop yields, which in the case of western Kenya is maize and beans. It does this primarily through a soil fertility effect – adding a significant amount of nitrogen and lesser amounts of other nutrients. Improved fallows also improve soil physical structure which can help moisture retention depending on rainfall amounts. Moreover, the fallows play an important role in terms of reducing prevalence of weeds and can reduce the number of striga plants, a very common parasitic weed. In addition to the crop effects, improved fallows also produce wood. The amount of wood produced depends on the species and the duration of the fallow. A study by Jama et al. (2004) found that the woody biomass from several different species in 1 season fallows ranged from 5.7 to 8.8 t ha^{-1}. For a two-season fallow, this changed only slightly to between 4.8 to 10.8 t ha^{-1}. Fuelwood is marketed in western Kenya and can fetch high prices. However, the value of the fuelwood from improved fallows is less than that from other sources for two reasons: the species used in fallows are inferior to those commonly sold on the market and the diameters of the stems are thinner than those preferred by buyers. Thus it has been estimated that the value of firewood is rather low – roughly USD 30 - USD 50 per hectare.

In addition to these benefits that accrue on the fallow plots, there are other environmental effects such as reduced soil erosion and carbon sequestration. Studies were carried out to assess the potential of improved fallows (under conventional and reduced tillage methods) to store carbon. The fallow system is not permanent but time averaged carbon storage can be measured. It was found that carbon sequestered (net of nitrous oxide emissions) was about 4 t ha^{-1} per year in soils with higher clay content and less in the sandy soils of western Kenya (Albrecht 2004). The price of carbon is fluid and expected to increase over time, but its price in 2004 was around USD 4 per tonne, giving a value of USD 16 per hectare per year (which amounts to less than USD 1.00 for the average size fallow).

5.1 *Effect of fertilizer tree systems on crop productivity*

Yield effects of fertilizer tree systems

Fertilizer tree fallows of just one season can increase substantially yields as compared to low or no input systems. The effect is particularly dramatic in the season following the fallow period. The results from a long-term trial over seven seasons, presented in table 3 below, attest to that. There is about a doubling of maize yields even with very short fallows and this increase is on par with the increase obtained through mineral fertilizer at this site.[5] This particular trial reveals that there is no crop yield advantage in prolonging the fallow period.

Table 3: Mean maize grain yield of 7 seasons (starting from 2000 - 2003) following improved fallows of different duration in western Kenya

Fallow duration	**Mean maize grain yield (t ha^{-1})**
Sesbania sesban (21 months)	2.3
Tephrosia candida (9 months)	2.2
Continuous Maize (NPK)	2.0
Sesbania sesban (9 months)	2.0
Tephrosia candida (21 months)	1.8
Natural Fallow (9 months)	1.4
Natural Fallow (21 months)	1.2
Continuous Maize	1.1
SED$^{\mu}$	0.36
LSD$^{\#}$ (0.05)	0.75

$^{\mu}$SED = standard error of difference of mean

$^{\#}$LSD = Least significant difference of means

Comparing single season yields is not the complete test of the fallow technology because land must be taken out of production for at least a season and this means that at least one maize harvest is ‘lost’. Research has shown that in most cases, total maize production in an improved

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[5] Note that there is quite some variation in results across sites. Often the yields in the no-input system are well below 1 t ha^{-1}. Sometimes the improved fallow effects are more than double and quite often the fertilizer effects are greater than those of improved fallows.

fallow system still beats the production in a continuously cropped maize system, despite the fallow period. For example, a farmer managed trial found that the total harvest from two seasons of maize growing following an improved fallow was 4.5 tonnes as compared to 4.1 tonnes from 3 seasons of growing maize without any inputs (De Wolf et al. 2000). A separate trial found that total maize production was 5.1 tons in 3 seasons following a fallow as compared to only 4.4 tons from 4 seasons of continuous cropping. A system with short natural (i.e. grass and weed) fallows turns out to be the worst by far in terms of total maize production.

Throughout much of western Kenya, soils are highly deficient in phosphorus. In such soils, while improved fallows alone sometimes still have a measurable impact on yields, the best interventions combine agroforestry with phosphorus fertilizers. Through many trials, we have found that modest phosphorus additions are just as effective as large doses and are obviously more inexpensive. An example is clearly seen in table 4 where *Tithonia* mulch in combination with phosphorus inputs gives a yield that is 8 times as high as the yield with no input and about 6 times higher than that of *tithonia* alone. These also turn out to be the most profitable management options. A similar story holds when discussing biomass transfer systems. The leaves provide a significant amount of nitrogen but less of the other nutrients. Biomass transfer systems do not provide soil infiltration

Table 4. Maize yield following application of equal rates of N, P, and K as either green biomass of tithonia or as mineral fertilizer in western Kenya.

Treatment	Nutrient added (kg ha^{-1})			Maize grain yield (t ha^{-1})^{a}
	N	P	K	
Control	0	0	0	0.5
Tithonia	60	6	56	1.3
NPK fertilizer	60	6	56	1.1
Tithonia + 50 kg ha^{-1} as TSP	60	56	56	4.2
NPK fertilizer + 50 kg P ha^{-1} as TSP	60	56	56	3.6
SED				0.42

The rate of *Tithonia* application was 1.8 t dry matter ha^{-1}

TSP = Triple superphosphate

SED = standard error of the difference in means; number of replication = 4

[a] Yield is adjusted to a grain water content of 15.5%

Source: Jama et al. 2000

and weed mitigation effects however, as they are grown ex situ. Nonetheless, the effects on yields are often a doubling or more and because land is not taken out of production total maize production over a period of time can be considerably more than if maize was continuously grown without inputs. While promising, it turns out that limitations in hedge areas to grow *Tithonia* and the labour requirements for transporting it to the field makes this system most practical for small plots.

Attempts were made to assess yield impacts of improved fallows and biomass transfer from a large number of practising farmers. Farmers using the systems outside of the pilot village area compared yields from different soil management options to a control case of maize production with no soil nutrient inputs. Table 5 shows that fertilizer, improved fallows, and biomass transfer all led to positive yield changes in most cases, with fertilizer being the most likely (93%) to lead to a positive change and improved fallows and biomass transfer just behind (for both, 88% of cases showing positive effect). All three practices were reported to have significant effects on yields, as reported by the percentage seasonal increase in median and mean yield. For example, median yield increases from biomass transfer and improved fallows were equal to 167% over a no- input maize cropping system. The agroforestry practices compare favourably with fertilizer probably because the amounts of fertilizer used by farmers are low, whereas farmers are able to generate significant amounts of nitrogen from the agroforestry systems on the relatively small plots on which it was applied.

Table 5: Soil fertility practices and maize yield impacts: assessments from farmers outside the pilot village area

	Improved Fallow	Biomass Transfer	Fertilizer
Number of cases	48	56	59
Compared to no inputs:			
Percent with non-positive effect	12.5	12.5	6.8
Mean increase in yield (%)	128	114	89
Median increase in yield (%)	167	167	122

Labour implications

Labour requirement for cutting and applying Tithonia

A major issue in the *Tithonia* biomass transfer system is the amount and cost of labour. The labour involved can be divided into two main components: one, the time needed for cutting; and two, for spreading and incorporating the biomass. Additionally, estimations were made for transport time in order to carry *Tithonia* to the farm, in the cases where it was collected from naturally growing stands. Time recordings were made for men and women and from hedges in different growth stages (Rommelse 2001). On average, the time taken to cut and apply one kg of fresh *Tithonia* material is almost two minutes. The overall average is 111 seconds per kg and the averages for the men and women become equal. When farmers collect *Tithonia* fresh material outside their farm, the modes of possible transport are walking, cycling or use of a wheelbarrow. If *Tithonia* is near the field, either can be relatively inexpensive but if far, it is necessary to have a bicycle to make transportation affordable in terms of labour time.

Labour requirement for improved fallow

This section examines two labour aspects connected to the use of the improved fallow technology (taken from Rommelse 2001): first, the labour requirement for cutting improved fallows is assessed: secondly, a comparison between the labour requirement for land cultivation between a continuous cropped plot and an improved fallow plot is made. The average cutting time is 52 hours per hectare with the median being 41 hours per hectare. As noted above, the average sized fallow is around 0.04 ha so that results in just about 2 hours of work. The labour time needed for land cultivation was also recorded. Land cultivation means ploughing manually, that is using a hoe. The aim was to compare plots with improved fallow and plots with prior continuous cropping. The results show that on a hectare basis the improved fallow plot needed on average 363 days and the continuous plot 308 days. The difference at the mean fallow size of 0.04 ha is just 2 hours. According to farmers, there is not much difference in digging the soil after a fertilizer tree fallow or after continuous cropping. Farmers claim that digging is most straining following a natural fallow because the soil has become hard. Over a four-season rotation, the fallow system uses only 83% of labour of the continuous cropping system.

Economic returns

Previous work from the late 1990s involving over 50 farmer-managed trials showed that improved fallow systems with maize were profitable. The seasonal per acre net gain to *Tephrosia* fallows was USD 22.33 and for *Crotalaria* was USD 19.96, compared to the returns from continuous maize with no nutrient inputs (Place et al., 2002). The same set of trials also assessed the returns to labour from fallowing systems, which were found to be around USD 2.17, or 33% higher than that from the no-input continuous maize production system. Returns to biomass transfer on maize in trials fared poorly due to high labour costs against relatively low value return from maize, but amounts of biomass in the treatments were substantially above amounts that are commonly applied by farmers.

These returns are suggestive of significant gains if the size of fallows planted by farmers were as large as one acre (which they are approaching in more land abundant Zambia). However, as was shown in section 4, in western Kenya, the average size fallow plot (as well as average size biomass transfer plot) is not large, just a fraction of an acre. To find more profitable opportunities, farmers have directed soil nutrient inputs from biomass transfer to higher value crops, rather than maize. Farmer-managed biomass transfer trials with kales and tomatoes have shown that similar increases in yields are obtained on these crops and because they fetch much higher prices, gross revenue is as much as 10 times that of maize on a per hectare basis and returns to land and labour can be 5 times or more than those from maize. In fact, we found that households shift the destination of biomass from maize to vegetable plots. In the non-pilot villages, vegetables constituted only 7% of biomass transfer plots in 1998, but by 2001, this figure had risen to 21%**.**

In surveys of farmers using the systems on their own, almost all households reported that their maize yields increased from the use of agroforestry technologies. Fertilizer, improved fallows, and biomass transfer all led to positive yield changes in most cases – in 93% of cases for fertilizer and 88% of cases for biomass transfer and improved fallows. In terms of a percentage increase, the median increase in yields from improved fallows and biomass transfer was 167%.[6]

5.2 *Effect of fertilizer tree systems on household assets*

If the yield impacts from fertilizer trees are going to lead to sustainable increases in livelihoods, then one would expect to observe some degree of asset accumulation. The qualitative research found that this was indeed occurring for some households, but not all. Patterns were difficult to detect with a small sample, but it was evident that because of rampant poverty, households were hard placed to convert any gains from increased yields into tangible assets. The few that were able to increase assets reported gains in livestock and housing. Several quantitative analyses were undertaken to confirm whether these mixed results hold across larger populations.

Before discussing the links between fertilizer trees and assets, it is extremely important to understand the context of assets and their change during the study period. Looking at the actual values, livestock comprises about 70-80% of the value of all liquid assets. For example, the mean total liquid wealth held by non-pilot village households was USD 408 in the survey year and of this livestock comprised USD 302. A large number of households (about 50%) suffered through dis-investment in both livestock assets and total assets over the 1999-2002 period. Some of the more wealthy households saw their livestock holdings collapse, through the selling for obligations (e.g. funerals) and disease (especially afflicting poultry). Using econometrics, it was found that the use of agroforestry was not strongly linked to the change in assets – they were unable to reverse what was for most households a loss in assets.

5.2.3 *Effect of fertilizer tree systems on household expenditure*

Expenditures for the previous three months were collected for the pilot village subsample of 103 households both in 1999-2000 and in 2002. All non-food expenditures were assessed (food expenditure data was too difficult to collect in a three month recall and food consumption is handled separately below). We analyzed changes in non-food expenditures per household and also per capita. For the latter, we divided by the number of household members. Median non-

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[6] We could not calculate absolute increases in yields because of problems in obtaining precise sizes of plots with and without agroforestry technologies.

food expenditures in 2000 were USD 60 and rose by about 10% over the period. Per capita non-food expenditures, on the other hand, were flat over time, with a median of just USD 10. Turning to the econometric analysis, the two agroforestry variables were found to have opposing effects on expenditures. Farmers using improved fallows were found to have worsened expenditures over time (after controlling for other variables) while those using biomass transfer systems had relatively more favourable changes to expenditures. Although this may be explained by the higher value crops associated with biomass transfer systems, the underlying reason for the fact that differences are observed with expenditures and not with assets, consumption or nutrition is not apparent.

5.2.4 *Effect of fertilizer tree systems on household food consumption*

Food consumption and nutritional measures were based upon 24-hour-recall surveys of households (three visits in 2000 and two visits in 2002) during a relatively hungry period before the long rain harvest. Household-level indicators of intake and nutrition were calculated based on age requirements of consuming members. Nutritional indicators were taken from FAO and USDA guidelines, depending on which was able to more accurately reflect the specific type of food consumed (e.g. cooked kales). The average household scores well in terms of fulfilment of energy, carbohydrate, iron, riboflavin, and niacin requirements in both years. Much of this comes from maize, as an analysis of baseline data revealed that maize accounts for 75% of the total nutritional energy supply. There is some diminished sufficiency in folic acid in 2002 and there are low levels of protein sufficiency reported in 2002. But even for those indicators that appear favourable in the aggregate, there are large numbers of households unable to meet their recommended needs. For instance, in 2002, 42% of households did not reach the required intake of energy, neither did 53% for folic acid, and 73% for protein. It is also interesting to note that there is a general decline in nutritional status over the two-year period – in fact, none of the variables exhibits improvement over time.

Econometric analyses focused on those nutrient measures that exhibited significant change over time: energy, protein, iron, and folic acid. None of the agroforestry adoption variables were found to be significantly related to changes in food intake and nutritional status. In fact, the only significant variable in each regression was gender of the household head, where female heads are associated with positive change (or less negative change) in each of the three indicators. Therefore, the dynamics of food intake and nutritional status appear to be very complex processes.

5.3 Evidence of impact from qualitative case study syntheses

It is generally observed that from the farmers' point of view, the different fertilizer tree systems adopted have impacted on their lives in terms of increased farm yields, raised household incomes, improved food security, and ability to mitigate vulnerable situations. The biggest incentive is the incomes deriving from the sale of seed, increase in yields, reduction in the 'hunger period,' the medicinal value derived from some of the shrubs, and general improved life styles due to raised farm incomes. The various case study accounts, however, also suggest that actual impact is also dependent on the circumstances under which these technologies are taken up.

The full potential of fertilizer tree systems technologies is realized on only a few farms. The qualitative studies show that where some of the larger impacts have occurred, the successful households had above average human capital resources or more diverse livelihood strategies on which to build. Some farmers were not yet able to benefit from the technologies to a significant extent because they were too old or too poor to undertake the complimentary investments (for example buying of improved maize seed) to realize good yields. So these agroforestry technologies appear to have mixed implications for impacting on poverty. On the one hand, the fact that the poor households are using them is in itself a positive sign. However, once adopted, the success of these technologies in generating significant welfare impacts is dependent on the household's ability to manage the complexities and opportunities stemming from the introduction of fertilizer trees. So, to summarize, the impacts of improved fallows and biomass transfer are noticeable in terms of yield increases, but for most households, these have not been large enough to translate into significant welfare impacts.

Nevertheless, there are those households that have succeeded anyway and the question is, why? Generally, both biomass transfer and cultivation of improved fallow do best among smallholder farmers, most of who engage in subsistence production and could therefore be classified as poor. But this particular category of rural dwellers is subjected to various vulnerabilities. The various case studies suggest that social networks are extremely crucial to one's ability to derive benefits from the technologies. For instance, some of the farmers only got to know about fertilizer tree systems from friends and neighbours who were already enjoying the benefits. Households that have diversified their sources of income cope better with some of the demands of implementing the technologies. Those households with relatively more land or an ability to cope with unpredictable labour demands (for example through substituting household labour with hired labour) found it easier to benefit from the agroforestry systems. This just emphasizes the existence of multiple constraints facing smallholder farmers. Impacts from any single intervention area, for example technology, will be enhanced with concomitant interventions to overcome other constraints.

Case 1: Alice in Siaya

Alice is the second wife of Erasto having been married to him for 11 years. Before Alice got married to Erasto she was married elsewhere where she had two children. She has no children with her current husband. Erasto has two wives and is a mechanic of ‘posho’ mill (cereal grinding mill) machines and spends most of his time outside the home as he is called time and again to repair broken down posho mill machines. When he is at home he does not participate in farm work physically. In her new home Alice’s relationship with her husband is fine though it is sour with the first wife who has even accused her of killing her son. But Alice says that her husband is considerate and does not blame her for not having a child. Therefore, she can stay on comfortably with him.

When the husband works well he may give her up to KES 100 when he comes back from two weeks of work away from home though this is not guaranteed. However, his contribution rarely reaches the KES 100. She may be given KES 100-200 per month on the maximum and only occasionally it may go up to KES 300. If she needs money to travel, like to attend a funeral at her place of birth, she may be given KES 500 at most. Her transport to and from Kogelo costs about KES 220. Alice says that for the last 5 years she has had funerals of her nuclear family yearly or twice per year. This has depleted her resources and is the reason she has no poultry of her own as she uses her chickens in the funerals or sells them for money.

Alice lives in a small grass thatched but well maintained house. The house is very small: it can hardly accommodate three visitors and her seated inside. The same house acts as the kitchen. Alice considers herself to be neither poor nor rich. When asked what she means by these terms she said: “A poor person has no food to eat, while a rich person has enough food until the next harvest and always has replenishment of what has been used up. A rich person also has enough money to address upcoming needs. Such a person is settled in mind.”

Alice obtains her livelihood through farming. She plants maize, beans, sweet potatoes, groundnuts, soybeans and bananas. The poultry she keeps belong to friends who have given these to her to keep for them. The size of the land on which Alice plants her crops is small: less than one acre. Since 1997 Alice has been using biomass transfer technology. She first heard about this technology through friends in the village. At the time it was introduced she was away from the village: she had gone to Kogelo to take care of her sick mother who later died. Thus before she heard the teaching from ICRAF staff, she started following what some of her women friends were doing. When ICRAF staff brought *Tithonia* cuttings into a neighbour's home for farmers to take and plant she took and planted like the others who had been taught.

Alice has planted *Tithonia* along the hedges of her farm and to partition crops in her small farm. During planting Alice says that she cuts down *Tithonia* with a panga into small pieces and uses one handful into every seed hole. Before she started using this technology she harvested 20 *gorogoro's* (about 40 kg) of maize and 2-3 gorogoros of beans on her small plot. With *Tithonia* the yields have increased to almost 2 sacks of maize (about 160 kg), 20 gorogoros of beans, 3-4 gorogoro of soyabeans and 1 gorogoro of groundnuts when she works well. That is if she uses the right amount of *Tithonia* in the long rains (chwiri.)

According to Alice the use of the fertilizer tree technologies as taught by ICRAF have increased her farm yields greatly. Because of this increment she does not have to keep looking to Erasto to provide her food. She is able to do quite a bit for herself. Alice says: "*Tinde ok aladhra kaka chon* - Today, I do not lack/miss food and look for small quantities just for daily survival like before. I have enough food." Without food in the house she had to beg from the husband and neighbours. "This is a bad habit. Initially I borrowed maize and depended on my husband for everything. This sometimes made us have disagreements especially when he did not have money and I had no food. Now, with his consent I can sell some of the produce for income to invest in farming/ploughing when I am unwell, buy paraffin, cooking fat, meat and other household items I lack. Sometimes I may also decide to sell a little and do my other shopping without necessarily consulting him but this I have done in secret. This is because men and women think differently and have different needs. And now that I have enough food in the house we (my husband and I) now we have more joy," she said.

Alice says that working with *Tithonia* is not very difficult but quite demanding. Yet she prefers it because it clears striga weed, cutch grass and increases yields without using the inorganic fertilizer. It's worth using, she applauds. The only hard job is chopping it into smaller pieces or when one has to harvest it from a far place. Alice explains how she adapted the technology for her use. She does not always chop the leaves as recommended nor cover the leaves with soil when placing them in the planting hole. This saves quite a bit of labour time.

Case 2: Gilbert and Hellena from Siaya

Hellena is the only wife of Gilbert, both of whom are over 70 years old. They have four adult children all married, two younger girls and three younger boys, though one girl died last year. Gilbert is a retiree from a factory job where he worked for more than 50 years. Since he came back home in 1993 they have worked in the farm for their consumption. Thus farm work is important as a livelihood strategy. Since his wife broke her knee bone in July 2000 he now works alone most of the time in the farm. Hellena does more of business of fermented finger millet (*thowi*).

Hellena cannot carry her load to and from the market, therefore Gilbert carries it for her on his bicycle. When he gets committed elsewhere they organize with a nephew or any other bicycle transport to take it to the market. “When I broke my knee and could not attend to the farm it was still possible to continue with this business because I could send someone like my husband or my daughter-in-law or any other relative to buy for me the dried finger millet from the market. I would be able to do other things and some of my customers would come to buy from me at home.” Actually now instead of purchasing 10 *gorogoros* of dried finger millet she can only strain to get 3 *gorogoros* to make *thowi.*

Gilbert owns 1.3 hectare of land and one cow. Most of the land is on a sloping area down to a water stream. He says this land has not been productive and requires soil fertility improvement. Though he heard of what ICRAF taught people earlier he did not adopt it until the year 2000 when he decided to plant *C. grahamiana* and *T. vogelli* on the infertile piece of land down the slope. “Repeated ploughing and planting on the same piece of land has depleted the soil fertility.” he said. That is why now he has decided to adopt bush fallowing to revitalize his soil. He got *C. grahamiana* and *T. vogelli* seeds from ICRAF and has planted on the sloping land now for one year.

He has planted *Tithonia* on *fanya juu* (a trench built to form a terrace). He has used *Tithonia* once during the previous season on two small pieces of his farm. He says he has decided to use *Tithonia* now because he has seen a female neighbour realize good yields from a small piece of land. When he used *Tithonia* as green manure he realized four sacks of maize (about 360 kgs) from two plots in which he used to get only about 2 sacks. This has encouraged him and he hopes to continue using *Tithonia*. They plant indigenous varieties of maize and beans since hybrids are not affordable. Gilbert used D.A.P once in 1994 but he says that fertilizers make soils unproductive and salty in the long run. Other times he uses boma manure but his cows were stolen and the remaining one cannot provide enough boma manure for his farm. They hope that continued use of *Tithonia* will increase their crop yields further.

He has also planted improved fallow species. Initially he planted *C. grahamiana* in order to sell seeds to ICRAF. He says “They (ICRAF) say that these fallow crops add manure to the soil and it may be true because though I have not planted food crops on the piece of land I see that the fertility has improved by looking at the types of weeds and the way they grow on the land. They look healthy.” He intends to clear and dig it when he gets capital to hire labour.

Hellena says poverty is a state of lack of the basic needs. When one is not able to afford basic needs like food then such a person is said to be poor. More emphatically she says: “A poor person can not carry out the farm work effectively because there is no source of income, but a lack of new workable ideas. Such a person has no food to eat and cannot send the children to school. Look at my grandchildren here; they can not go to school because their parents can not afford it. Now I am trying to work hard to get for them some money to send them back to school.” “The soil fertility management methods taught by ICRAF can help to eradicate poverty as they increase crop yields. Thus reducing hunger. Good farmers use these methods and prepare their land adequately before they plant their crops. They also carry out soil conservation measures to avoid soil erosion and plant various crop varieties to spread the risks of crop failure. This is because these days crop failure is common and if only one crop variety is planted then when it fails the whole household is at risk of hunger. This implies that a good farmer must work very hard to cope with the work involved.”, Gilbert explained. They said that though they are old they still work hard to make sure they produce their food.

In summary, impacts on yields are significant and consistent over many households. But because improved fallows and biomass transfer systems occupy very small land areas, these yield impacts have not translated into significant – that is detectable – changes in household level welfare indicators.

6. Dissemination of fertilizer tree technologies: comparing approaches

As part of ICRAF’s research on soil fertility replenishment technologies in western Kenya, the initial dissemination processes were also studied. This was important because: (1) dissemination approaches used by organizations in western Kenya are intended not only to disseminate technology, but to strengthen human and social capital such that farmers can continue the dissemination process inside the village and ultimately in other villages; (2) dissemination methods and experiences affect these organizations’ ability to reach the poor and women – in other words, the process of dissemination can have as much impact on adoption as the nature of the technology itself.

A range of different organizations were disseminating the fertilizer tree systems each using a slightly different ‘dissemination approach.’ All share certain characteristics and differ in other ways. They all enter villages with the assistance of local administrators, and seek to determine local problems and solutions through broad meetings or local groups. They then work with groups for the purpose of facilitating the dissemination of new locally adapted technologies in a sustainable manner. These groups may be existing community groups (for example women's, youth, church, self-help groups, or groups based on clans), or new groups formed for this purpose. Some also use umbrella structures formed of representatives from groups across different villages, to provide support structures and liaise with external organizations. All approaches use a variety of teaching methods, involving field days and demonstrations, observation, use of schools, and others (see below), though they have different emphases. For example, methods used by CARE and the Kenya Agricultural Research Institute emphasize substantial training of lead farmers who are then to disseminate knowledge to others. The village approach (used by ICRAF) worked both with groups and individuals, through a more formalized representative committee in a pilot area. The extension service's catchment approach was implemented through a newly established committee down to farmers, but did not interact much with existing groups.

6.1 Evaluation of external disseminating organizations

The four most active organizations (ICRAF, MoARD, CARE, and KARI) score approximately equally according to their usefulness and importance. Overall, the assessment of disseminating organizations is positive. The main problems raised were: insufficient staff, insufficient time given to farmers, their leaving too soon - "What limits full implementation is that they are usually left before standing on their feet", and insufficient monitoring. ICRAF also was favoured for the links it was said to have with farmers. However, many farmers were dissatisfied with ICRAF's use of individual contacts to organize dissemination activities (these were village committee chairmen). With this strategy certain villagers gained a lot of attention from ICRAF/KEFRI/KARI in their endeavours to introduce and disseminate agroforestry technologies in the region. This caused some of the farmers to cease to attend the meetings and workshops organized by ICRAF staff.

6.2 Farmers' assessments of teaching methods

Each of the dissemination approaches uses a combination of teaching methods. The first group of methods involves forms of training organized by external organizations, for example demonstrations, field days, tours, exchange visits, and farm visits. A second set involves different types of meetings, formal or informal, that targets specific individuals or are open to the public, and discuss future plans, resolve issues, monitor progress, or identify needs. Finally, there is observation of others' fields and oral conversation. All three forms of teaching were popular, and people prefer a mix of all of them. Although they varied greatly by village, informal means such as learning through observation are highly rated, despite the fact that they did not involve external resources or organized activities. Very few differences in opinions on methods emerge based on gender and wealth status. An important finding to emerge is that people value the formal methods a great deal. Some specifically said that they would prefer more visits in their homes – the more traditional approach. This reinforces the key challenge for dissemination – how to balance the need for engagement with individual farmers with the need to reach a large number of them. Some degree of farmer input was solicited in all approaches, and respondents from at least three of the six villages mentioned this specifically.

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6.3 The spreading of information within villages

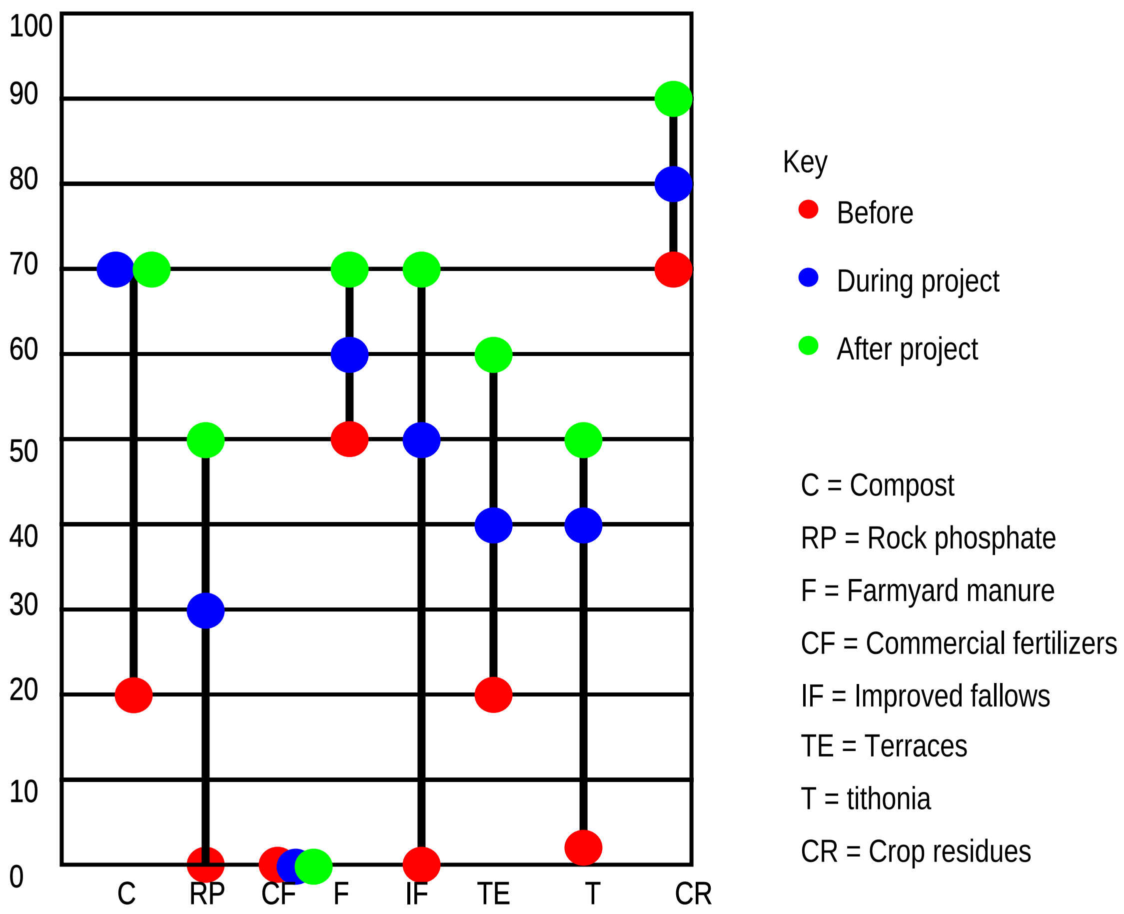
As discussed above, each of the dissemination approaches relies on local groups for disseminating the technology across a wide group of farmers, and for ensuring sustainability. These groups were scored as a relatively important source of information, and in some cases were said to be working well. Yet they have also experienced many problems. In most villages there were reports that they had performed poorly with respect to providing information to other farmers. One problem is the lack of participation in the groups, either because of self-exclusion or exclusion by group members. Low levels of participation directly in the groups would not be as large a problem if the groups were conducting dissemination activities with other farmers as envisioned. However, this has also been insufficient. Five of the six villages studied reported one or both of these problems. All women said that domination by men in the groups reduces women's participation and learning. This shows the importance of having separate groups for men and women.

In five of the six villages, many respondents said that the fertilizer tree interventions and extension activities had brought their community closer together. However, local groups also introduced social tensions and politics. One or more of the following issues were reported: uneven distribution of resources, discord over extra attention that some farmers received from external organizations, failure of extension staff to visit farmers, the ability of some to amass wealth through the process, conflicts over resources, rivalry among leadership and mismanagement of funds. In most of the villages, it was recognized that the interventions led to competition and conflict in some ways and to cooperation and cohesion in others.

6.4 Knowledge acquisition

Although focus group participants have varying opinions of disseminating organizations and their methods, the best measure for assessing the performance of these organizations is the amount of knowledge people gained through the dissemination efforts. A total of seven soil fertility management technologies were mentioned as discussed across all six villages: *Tithonia*, farmyard manure, compost, commercial fertilizer, rock phosphate, improved fallow, and crop residues. Groups used a 'ladder' technique to show the amount of knowledge on the technology they had before and since the dissemination approaches (see figure 3). For the vast majority of groups, the starting point was zero for most of these technologies. The most surprising finding about the amount of knowledge gained is its uniformly high levels. For *Tithonia* biomass transfer and improved fallows, knowledge gain was substantial (in terms of the ladder scoring, there was roughly a 50 percentage point increase). Analysis of household data found that agroforestry knowledge acquisition was linked to direct contact with ICRAF, NGOs, or CBOs, but not to direct contact with extension or other farmers. According to participants, those with more education generally learn more about the technologies than those with less. Nonetheless, the difference is less dramatic than one may expect, indicating that disseminators are reaching vulnerable groups. There are not particularly large differences by gender and wealth either.

Figure 3 Sauri poor women's group, at least four years of primary education



7. Summary and conclusions

There was a general deterioration in welfare indicators during the period of study. This holds true for assets, expenditures, and food consumption. Particularly striking was that households with relatively high welfare indicators in the initial period suffered the greatest losses. This is due partly to the large number of adverse shocks affecting households and the cultural obligations felt by all community members (for example the wealthier households contribute animals for slaughter at funerals).

Farmers appreciated the efforts of different disseminating organizations and the many different methods tried. They particularly appreciated direct contact and field observation methods and to be able to access information through a variety of channels. Some problems in the transmission of information have occurred when organizations have relied on a few individuals of community to spread information to others. When information was transmitted to farmers, it was highly valued and often put into practice. However, for many different reasons and constraints they do not apply these technologies to maximize the possible returns from them. In the case of fertilizer tree systems adoption rates in some focal villages are encouraging especially among the poor. Yet, the sizes of plots on which they are applied remain small.

Researcher managed trials and farmers' responses consistently report very significant increases in yields (> 100%) from the use of improved fallows and biomass transfer practices. But these systems on their own cannot bring about a turn in poverty reduction. This conclusion is drawn from the body of impact assessment work. Despite the fact that the agroforestry systems are being used by a number of poor households and are having an impact on yields, the impact at the household level is modest. This is due to the small land sizes under the fertilizer tree systems and because the weak rural economy is not conducive for investment and development.

Pathways out of poverty are varied and highly uncertain. Identifying clear strategies through agriculture is equally difficult due to low prices, variable climate and high costs of profitable investments. Small land sizes in turn limit the amount of diversification that households are willing to undertake. It seems that in order for widespread poverty alleviation to take place, many components of the rural socioeconomy need to be functioning well. Even if progress is made, households can easily slip back into poverty.

Within agriculture, poor households can take initial steps by building on crops/enterprises that they already have. The strategy under consideration in this study was a relatively safe one of increasing yields of the basic staples of maize and bean. What is the future for agroforestry in all of this? The soil fertility systems being disseminated are a useful option for farmers and it has been shown that these options are being tried by many of those with no prior record of investment in soils. There are clear limitations to the use of improved fallows and biomass transfer, however. Small farm sizes limit the extent to which niches can be found to produce the green manures. A relatively new fertilizer tree system, a permanent tree-maize intercrop system may hold more promise on the very small farms. The system enables maize to be grown continuously without a fallow and is proving to be highly attractive in the highly densely populated areas of southern Malawi. Even so, improved soil fertility management for these smallholder farmers will undoubtedly encompass a range of management practices, using both organic and mineral sources.

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