AN AGRONOMIC AND FINANCIAL ANALYSIS OF UNDERSOWING WITH *TEPHROSIA VOGELII* AND MAIZE IN MALAWI

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ABSTRACT

Two undersowing trials with *Tephrosia vogelii* and maize were analysed. The first evaluated 3rd season results of 56 farmer-managed sites where undersowing with a fallow season under reduced tillage was compared with continuous maize cultivation under conventional and reduced tillage. Sites were typical of smallholder farms with moderately to severely degraded soils. In scenarios with and without fertilizer, yield and gross margin returns of undersowing were better than sole maize under both conventional and reduced tillage. Undersowing without fertilizer increased yields by 50% and 100% over sole maize under conventional and reduced tillage respectively. However, a cost-benefit analysis shows that undersowing with a fallow season is recommended only with fertilizer due to the loss of production in the fallow phase unless this land is not planned for cultivation. Sole maize under reduced tillage gave lower yield and financial returns than conventional ridging. This result was likely due to the degraded low organic content of soils, which limit the rooting depth of crops when not tilled. The second trial analysed the 2nd season results of an annual system of undersowing which showed highly beneficial yield and financial returns vs. sole cropped maize in scenarios with and without N fertilizer.

1.0 INTRODUCTION

This paper presents an agronomic and financial analysis of two separate trials on undersowing with *Tephrosia vogelii*. The first trial includes data collected from 56 farmer-managed sites across the country (Bunderson et al., 1996). The other is a replicated trial managed by extension staff in Dedza Hills. Details of each trial are presented below.

2.0 SITE LOCATION AND TRIAL DESIGN

2.1 Trial 1: Agroforestry – Reduced Tillage Trial/Demonstrations

A multi-locational 5 year trial was initiated in the 1996/97 season to demonstrate specific agroforestry and soil conservation practices to farmers in Malawi, and to evaluate a system of reduced tillage against the standard practice of ridging with hand-hoes. Treatments of relevance to this paper are described below:

Continuous maize cultivation under conventional ridging with hand hoes:

These plots served as a control for comparing reduced tillage practices. Conventional tillage involves cultivating maize each year on contour ridges built with hand hoes 90 cm apart. This is the common method of land preparation among smallholders in Malawi. It involves an enormous amount of manual labour, and there is evidence that it contributes to soil erosion and declining fertility, particularly under conditions of continuous cereal cultivation with low inputs. Moving the soil accelerates oxidation of organic carbon from the soil. Lack of organic carbon to bind soil aggregates means that soils are more exposed to raindrop action and erosion. Turning the soil also disrupts natural aeration and the beneficial actions of soil micro-flora and fauna.

Continuous maize cultivation in planting holes with no ridging:

These plots involve cultivating maize each year under reduced tillage. The concept is to minimize damage caused by annual deep tilling of the soil, as well as to reduce the labour of ridging. Ridging was carried out in the normal way for the first year. Thereafter, no further ridging was performed, but holes were dug to a depth of 20 cm immediately after the first year's harvest to break through the hard crust of the soil surface. Each hole corresponded to the location of planting stations. Digging holes to this depth was a one-time activity since the beneficial actions of reduced tillage with stronger root systems of crops grown, were expected to maintain good soil structure and permeability. Crop residues were left on the soil surface as mulch and to increase the organic matter content of the soil. The same planting stations were used each year. Five light weedings were carried out during the growing season to reduce disturbance to the soil and to eliminate weed competition.

Undersowing *Tephrosia vogelii* with maize under reduced tillage with a 2nd season fallow:

This practice involves undersowing *Tephrosia* with maize in year 1 with normal ridging. Sowing involved 2 stations of *Tephrosia* between maize stations on every ridge at 3 seeds/station 2 cm deep. In year 2, *Tephrosia* was left as a fallow with no tillage. It was then cut down just before the onset of year 3. Leaf biomass was left on the soil surface and stems were removed for fuelwood. Thereafter, maize was cultivated under the system of reduced tillage described above. *Tephrosia* will be undersown again at the start of year 5 to repeat the cycle. The rationale for undersowing with a fallow season is that recent evidence from different land-use surveys in Malawi indicate considerably more fallow or idle land in the smallholder sector than originally thought (Hayes, 1999; Berger, pers. comm.). Much of this land has either been abandoned due to over-cultivation, or households lack the ability to cultivate their entire land holdings. This presents a unique opportunity to restore these degraded or little used lands to productive use by introducing a simple, low input, short-term fallow. This practice has shown excellent results in Malawi and neighbouring Zambia under both on-station and on-farm conditions. It involves intercropping maize in the first year with fast-growing, n-fixing shrubs such as *Tephrosia vogelii*. In the 2nd season, cultivation is abandoned, allowing the tree fallow to mature. At the onset of the 3rd season, the trees are cut down at ground level, leaving the root and leaf biomass to decompose in situ. Bare branches may be removed for firewood or other uses. Cropping is then resumed for 2 years, relying on the improved fertility status of the soil. One concern is that *Tephrosia* is prone to nematodes, which may introduce problems if tobacco or other susceptible crops are grown on the same land. Another concern is the loss of land for 1 out of 4 years. It is contended that such losses will be compensated by gains in crop productivity and income from seed harvests.

The trials were established and managed by smallholder farmers in all 8 ADDs with supervision from extension staff. Sites represent typical soil and farm management conditions to accurately reflect how the practices discussed operate in the real world of the Malawi smallholder. Each farmer had an unreplicated set of 10 m x 10 m plots for the different elements under demonstration. Sites were split to evaluate the effect of fertilizer application on the different practices, giving a total of 6 comparisons, which were analysed across sites:

1. Continuous maize under conventional tillage, no fertilizer
2. Continuous maize under conventional tillage, with fertilizer (see rates below)
3. Continuous maize under reduced tillage + retention of crop residues, no fertilizer
4. Continuous maize under reduced tillage + retention of crop residues, with fertilizer
5. Undersowing *Tephrosia* and maize under reduced tillage in year 1 no fertilizer, fallow in year 2, sole maize in year 3 with reduced tillage, no fertilizer
6. Undersowing *Tephrosia* and maize under reduced tillage in year 1 with fertilizer, fallow in year 2, sole maize in year 3 under reduced tillage, with fertilizer

Rates of fertilizer used per hectare for all fertilizer treatments are as follows:

Years **1 & 2**: Super D + CAN for a total of 47 kg N, 54 kg P_2O_5, 45 kg K, 13 kg S, 0.2 kg B
Year 3: CAN at the rate of 46 kg N

2.2 Trial 2: Dedza Hills Annual Undersowing

This trial is located in the grounds of the Dedza Hills Residential Training Center where it was managed by extension staff from the Department of Land Resources Conservation with supervision from MAFE officers. The trial was laid out as a randomized block design with plots measuring 10 m x 10 m in 4 replications of 5 treatments each:

1. Continuous maize, no fertilizer
2. Annual undersowing of *Tephrosia* and maize, no fertilizer
3. Undersowing of *Tephrosia* and maize in year 1, left fallow in year 2, then maize cultivation resumes in years 3 and 4 without *Tephrosia*.
4. Continuous maize with CAN at the rate of 96 kg N/ha
5. Annual undersowing of *Tephrosia* and maize with CAN at the rate of 48 kg N/ha

The trial has just completed its first season after the establishment year. Results presented on maize yields therefore exclude treatment 5 because it was in its fallow season.

3.0 AGRONOMIC RESULTS

3.1 Trial 1: Agroforestry – Reduced Tillage Trial/Demonstrations

Table 1 shows the 3rd season maize yields from this trial (see **Appendix 1**). A sample of 21 sites was used to determine biomass yields of *Tephrosia* at the time of harvest just before the rains. The average stem and leaf biomass on a dry matter basis was 12,702 and 1,814 kg/ha respectively. Leaf biomass excluded litter fall which was substantial over the dry season.

Effects of Undersowing

Use of fertilizer and type of practice significantly affected maize yields. Undersowing gave the best yields in scenarios with and without fertilizer. In the absence of fertilizer, undersowing increased yields by 50% and 98% over sole maize under conventional and reduced tillage respectively. The relative difference was less dramatic with fertilizer, but undersowing yields were still 600 and 1000 kg higher than conventional and reduced tillage respectively. From an agronomic perspective, these results clearly demonstrate that undersowing with *Tephrosia* is a beneficial practice under smallholder conditions with and without fertilizer.

Effects of Reduced Tillage and Retention of Crop Residues

Contrary to expected results, maize yields were depressed under reduced tillage relative to conventional ridging. The retention of crop residues on the surface to improve soil physical and biological properties appeared to have little effect because of the limited quantity of residues available and their disappearance from termite activity early in the season. This meant little surface protection and return of organic matter to the topsoil. These results suggest that the compacted, degraded and low organic matter state of smallholder soils limit the root growth of crops under conditions of minimal tillage. The implication is that this system of reduced tillage needs a more fertile base with excellent farm management, a situation requiring a longer timeframe for the needed changes in soil conditions. One could argue that this was achieved to some degree with undersowing from the large addition of quality biomass to the soil, which also offered simultaneous protection of the soil surface as it was not consumed by termites. However, without a control of undersowing using conventional tillage, the magnitude of this effect remains unknown.

3.2 Trial 2: Dedza Hills Annual Undersowing

Table 2 shows the 2nd season maize yields from this trial (see **Appendix 1**). The average stem and leaf biomass on a dry matter basis was calculated as 2,329 and 588 kg/ha respectively. Leaf biomass excluded litter fall which was substantial over the dry season.

The results demonstrate a significant yield response by undersowing with and without fertilizer. In the latter scenario, undersowing increased yields by over 49% relative to sole maize with no fertilizer. It also yielded only 17% less than sole maize with the full rate of nitrogen fertilizer. Half the rate of nitrogen fertilizer increased maize yields from undersowing by 31%. This was a 10% increase over the sole maize with the full rate of nitrogen fertilizer, but at considerably lower cost. Although this trial was managed by extension staff in a site with a fertility base higher than average smallholder soils, the results probably reflect the achievement of an above average farmer.

4.0 FINANCIAL ANALYSIS: METHODOLOGY

Nair (1990) argues that financial considerations are the prime factors that determine the advantage of agroforestry to the farmer. This sentiment is also expressed by Hosier who argues that "*for smallholders throughout the developing world to adopt agroforestry techniques, they must be convinced that the benefits of such innovations exceed the costs. Thus for agroforestry to successfully spread, it must be economically profitable to the smallholders who are practicing it*" (Hosier, 1989, pp.1827).

Therefore, having examined the agronomic aspects of the trials above, it is necessary to extend these to financial interactions. This requires an evaluation and comparison of all the financial costs and benefits of the practices on trial. For the agroforestry practices, costs are made up primarily of labour for such operations as planting and cutting down, with benefits derived from agronomic net benefits in the form of incremental maize yields, and tree by-products.

In contrast to annual cropping enterprises, the costs and benefits of undersown fallows are spread over time. This complicates the financial analysis and is addressed through long-term investment analysis techniques which account for the ebb and flow of costs and benefits over time.

4.1 Gross Margin Analysis

Gross margin analysis (GMA) is a commonly used farm planning technique and involves comparison of gross margins per hectare (or per head for livestock) for different enterprises (Barnard and Nix, 1993). The gross margin of an enterprise is "*its enterprise output less the variable costs attributable to it*" (Barnard and Nix, 1993, pp.45). Variable costs are defined as those that are specific to the enterprise and vary in direct proportion to the size of the enterprise e.g. fertilizer and seed in the case of arable crops. The output is determined by multiplying the enterprise yield by the price of the product.

The advantage of GMA is that, although based on budgeting procedures, it is more computationally efficient as it does not require full cost accounting (Barnard and Nix, 1993). The major disadvantages are that, as for budgeting, it is not an optimising technique, and in addition it ignores fixed costs (Scherr *et al.*, 1992). The latter criticism is not serious in the Malawian context as the smallholder cropping system has a limited fixed cost element in the form of fixed structures or machinery. Therefore, GMA is selected as the method for short-term financial evaluation for reasons of computational efficiency.

This method is acceptable when comparing two annual enterprises, but a problem arises with regard to comparisons between annual enterprises and those with a gestation period longer than a year, such as undersown fallows. The issue here is at which point in the cycle to compare gross margins. At the start, the long-term enterprise is discriminated against as benefits of the technology are yet to appear. At maturity the long-term enterprise is favoured as full benefits are apparent whilst establishment costs are ignored.

For maize-based agroforestry practices, the second option is a useful exercise in order to get a perspective on the comparative gross margins that the farmer can expect once the agroforestry practice has matured. The long-term financial viability of the practice, including establishment costs, is addressed in the next section using time-discounted cost-benefit analysis (CBA).

4.2 Cost-Benefit Analysis

A number of methods of assessing the value of longer-term enterprises have been developed, their common theme being a valuation of the incremental costs and benefits associated with the enterprise discounted over time. Although it is valid to compare the stream of benefits and costs over time of a particular enterprise without discounting, this assumes that the farmer is indifferent between current and future consumption. Nevertheless, discounting is one of the most controversial features of cost-benefit analysis (Scherr *et al.*, 1992), largely due to uncertainty over selecting the discount rate.

The most commonly used rate is the ruling bank saving or lending rate (Gittinger, 1989; Christopherson, 1991) although it has been suggested that these rates discriminate against longer-term enterprises (Pearce and Turner, 1990), such as agroforestry. The solution to this is the use of the ‘social time preference rate’ (Gittinger, 1989; Christopherson, 1991; Williams, 1992) which should be lower, reflecting the longer time horizon for society than for the individual (Gittinger, 1989). On the other hand, Hosier (1989) and Williams (1992) argue that peasant farmers prefer current consumption and as such have a high discount rate.

The bottom line is that there is no general agreement on the criteria for determining the choice of discount rate (Abalu, 1975). Abalu, evaluating perennial crop production in Cameroon, opted to use the ruling government borrowing rate as the discount rate. This convention is followed in this paper, as the focus is on the financial costs and benefits to the farmer, as opposed to the nation.

Benefit-Cost (B/C) Ratio

The B/C ratio is calculated by dividing the present value of the benefit stream by the present value of the cost stream as follows:

$$\frac{\displaystyle\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\displaystyle\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

The formal selection criterion for this measure is to accept all investments with B/C ratio greater than or equal to 1 when the cost and benefit streams are discounted at the opportunity cost of capital. Gittinger (1989) argues that ranking projects on this basis is not recommended as projects with high costs and benefits are discriminated against. The major disadvantages of the B/C ratio are that the result is dependent on where netting out occurs in the stream of costs and benefits (Gittinger, 1989; Williams, 1992) and a discount rate needs to be selected. One advantage is that it is a useful measure for establishing by what percentage costs would have to increase (or benefits fall) to make a project financially unattractive (Gittinger, 1989). As such, the B/C ratio is selected as the measure of investment appraisal in this paper as it provides a useful yardstick for comparison between alternative farm enterprises.

5.0 FINANCIAL ANALYSIS: RESULTS

This section undertakes a financial analysis, both short and long-term[1], comparing the agroforestry practices to a number of annual non-agroforestry maize production options. First, the full range of maize production practices that are evaluated are listed. Second, the GMA and CBA results are presented, discussed and conclusions drawn.

5.1 Trial 1: Agroforestry-Reduced Tillage Trial/Demonstrations

The following six trial plots were analysed, with assumptions and workings in **Appendix 2**:

1.	Maize conventional tillage	CT 0N
2.	Maize +N conventional tillage	CT +N
3.	Maize reduced tillage	RT 0N
4.	Maize +N reduced tillage	RT +N
5.	Maize Tv reduced tillage	Tv 0N
6.	Maize Tv +N reduced tillage	Tv +N

Gross Margin Analysis Results

The GMA results for the reduced tillage trial results are presented in **Figure 1** (see **Appendix 1**), in descending order. The gross margins for all options are calculated for Year 3. The fertilized undersowing with *Tephrosia* option returns the highest hectare gross margin (MK 14,508) followed by conventional tillage fertilized maize (MK 9,601) and reduced tillage fertilized maize (MK 9,141). All of the unfertilized options return significantly lower gross margins, with both the conventional and reduced tillage unfertilized alternatives showing negative gross margins.

These results suggest that:

- with fertilizer, application to maize undersown with *Tephrosia* is the best option
- without *Tephrosia*, conventional tillage makes more financial sense than reduced tillage both with and without fertilizer
- without fertilizer, undersowing *Tephrosia* is a better option than not undersowing irrespective of the tillage regime

Cost-Benefit Analysis Results

The CBA results, discounted over a twenty year time horizon with conventional tillage with no fertilizer as the base case, are illustrated in descending order in **Figure 2** (see **Appendix 1**). At a discount rate of 50%, in line with commercial bank lending rates and the MRFC credit rate, the three fertilized options return B/C ratios greater than one, with the fertilized *Tephrosia* option showing an excellent result. Reduced tillage with no fertilizer is not a recommended investment option as the labour cost savings are less than the fall in maize income due to the lower yield generated. The unfertilized *Tephrosia* option is also not financially attractive in the long-term as the incremental yield does not match the extra labour costs and loss of harvest in the fallow year, unless that land is not targeted for production in that year.

[1] The Dedza trial is only subjected to gross margin analysis as all the options are annual.

The following conclusions can be drawn from the above gross margin and cost-benefit analysis:

- maize production under the reduced tillage system is not recommended as an alternative to conventional tillage as lower yields are not matched by reduced labour requirements

- undersowing with a 2nd season fallow is recommended only if fertilizer is applied.

5.2 Trial 2: Dedza Hills Annual Undersowing

The following four trial plots were analysed, with assumptions and workings in **Appendix 2** (Note that undersowing + fallow was excluded as it was in its fallow season):

1.	Maize conventional tillage	Mz 0N
2.	Maize Tephrosia	Tv 0N
3.	Maize Tephrosia +N	Tv +N
4.	Maize +N conventional tillage	Mz +N

Gross Margin Analysis Results

The GMA results for the Dedza annual undersowing trial results are presented in **Figure 3** in descending order (see **Appendix 1**). The gross margins for all options are calculated for Year 2. The following conclusions can be drawn from the GMA results above:

- it makes better financial sense to produce hybrid maize with a combination of organic and inorganic fertilizer rather than using one nutrient source in isolation
- when used in isolation, organic fertilizer in the form of *Tephrosia* provides a better financial return than inorganic fertilizer.

6.0 CONCLUSIONS

Undersowing *Tephrosia vogelii* with maize is clearly a highly beneficial practice for smallholder farmers in Malawi, generating high yield and economic returns for reasonable levels of labour. The results show that a modest addition of N fertilizer will provide a more substantial and secure return to the average farmer if resources permit the purchase of fertilizer. To provide a more comprehensive understanding of undersowing with *Tephrosia,* further research is recommended to investigate long-term effects on crop yields and on the physical, chemical and biological properties of soils. The system of reduced tillage presented here suggests that conventional ridging should be continued, as long as it is done on contour, otherwise water runoff and loss of valuable topsoil will increase, leading ultimately to sheet and gully erosion with consequent reductions in farm productivity.

7.0 ACKNOWLEDGEMENTS

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APPENDIX 1: TABLES AND FIGURES

Table 1: Maize Yields (kg/ha) Trial 1: Agroforestry-Reduced Tillage Trials/Demos, 1998/99

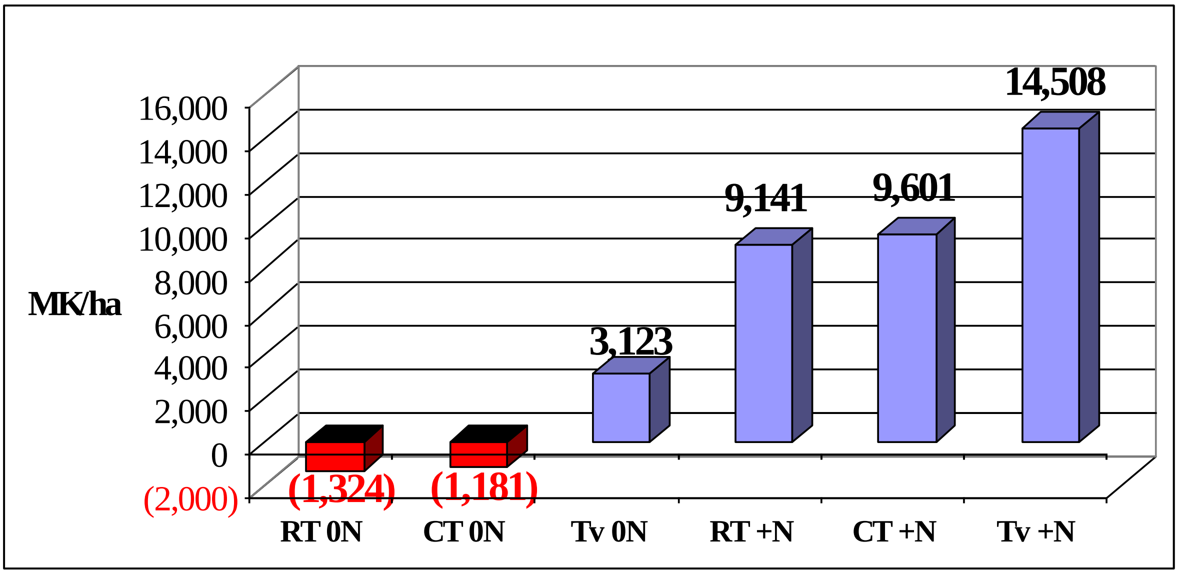
Treatment Effects	Continuous Maize, Conventional Tillage	Continuous Maize, Reduced Tillage	Undersowing *Tephrosia* with 2nd Year Fallow	Means	Probability > F
Type of Practice	2770	2478	3376	2875	0.0315
Fertilizer					< 0.0001
Without	1146	871	1720	1244	
With	3922	3502	4536	3970	

Table 2: Maize Yields (Kg/Ha) Trial 2: Dedza Hills, 1998/99

Treatment Effects	**Means**
Maize, no fertilizer	1665
Maize + 96 kg N/ha	2989
Undersowing, no fertilizer	2486
Undersowing + 48 kg N/ha	3266
Overall Mean	2601
Probability > F	< 0.0001
Standard Error	40

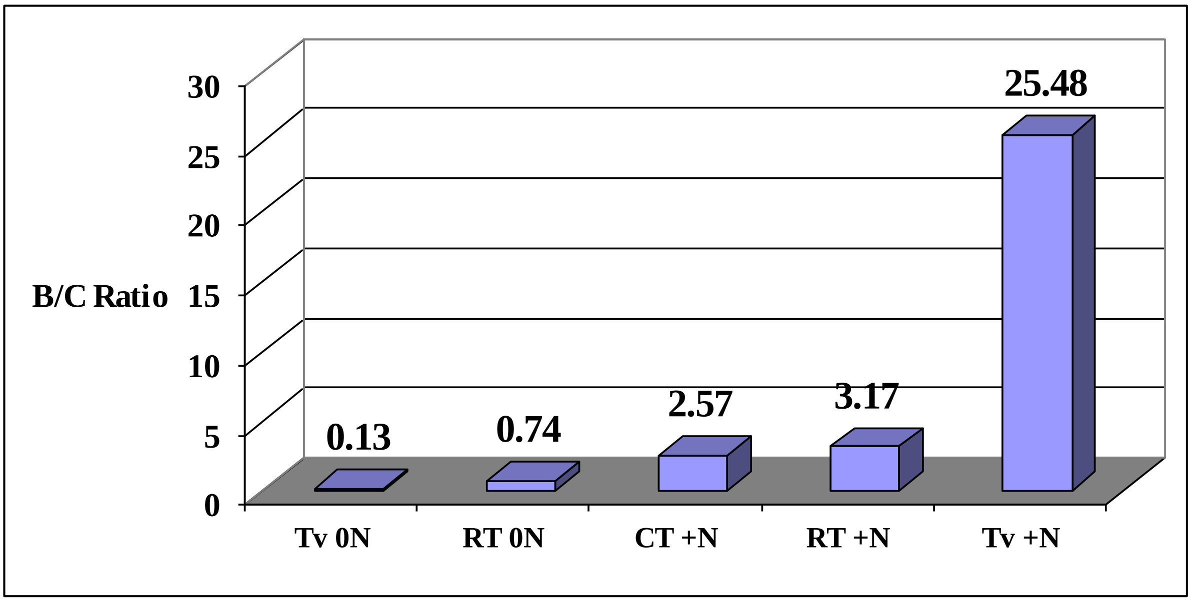
Figure 1: Hectare Gross Margins (MK/ha)

Trial 1: Agroforestry-Reduced Tillage Trials/Demos, 1998/99



Source: Appendix 2

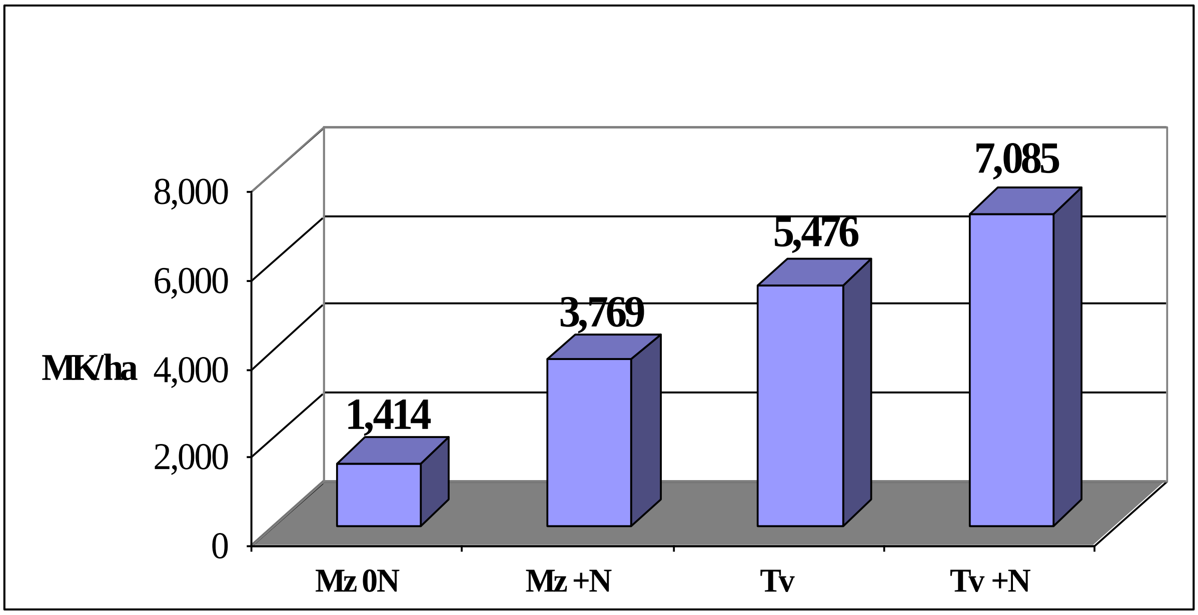
Figure 2: Benefit-Cost Ratios (at 50%) Trial 1: Agroforestry-Reduced Tillage Trials/Demos



Source: Appendix 2

Figure 3: Hectare Gross Margins (MK/ha)

Trial 2: Dedza Hills, 1998/99



Source: Appendix 2

APPENDIX 2: TRIAL 1 and 2 GROSS MARGINS

Labour Details (Days)

Maize		**Undersowing**	*T.vogelii*
Clearing	25	Planting	13
Ridging	52	Cutting	16
Planting	11		
Weeding	42		
Banking	44		
Basal Fert	9		
Top Fert	5		
Harvesting	46		
	233		

Own Labour Rate (MK/day)	**Wood Price (MK/mt)**
23.52	**900.00**

Wood Yields (MT/ha)	**USFall**	**USowing**
Year		
1	0	0.78
2	4.27	0.78
3	0	0.78
4	0	0.78
5	-	0.78
6	4.27	0.78
7	-	0.78
8	-	0.78
9	-	0.78
10	4.27	0.78
11	-	0.78
12	-	0.78
13	-	0.78
14	4.27	0.78
15	-	0.78
16	-	0.78
17	-	0.78
18	4.27	0.78
19	-	0.78
20	-	0.78

Fertiliser Rates (kg/ha)

	Year 1	**Year 2**	**Year 3**
Reduced Tillage Trials	225 kg Super D	225 kg Super D	170 kg CAN
All fertilised plots	90 kg CAN	90 kg CAN	

	Year 1	**Year 2**
Dedza Trial		
Fertilised maize plot	80 kg DAP	80 kg DAP
	175 kg Urea	175 kg Urea
Fertilised Tv plot	40 kg DAP	40 kg DAP
	87.5 kg Urea	87.5 kg Urea

Notes:-

1. All maize labour details are compiled from 1995/96 survey data (Hayes 1999) and reported in 6 hr day equivalents.
2. Undersowing labour data estimated.
3. Own labour rate is the return per day to unfertilised non-hybrid maize.

4. The wood price is calculated from a limited wood price survey undertaken in Lilongwe district in September 1999 by the MAFE Project.
5. *Tephrosia* wood assumed to be 1/3 of the calorific value of hard wood.
6. Wood yield data: Undersown fallow wood yield data sourced from MAFE Project Reduced Tillage Trial results Yr 2; undersowing yield data is sourced from MAFE Project Golf Club Trial data 1997