

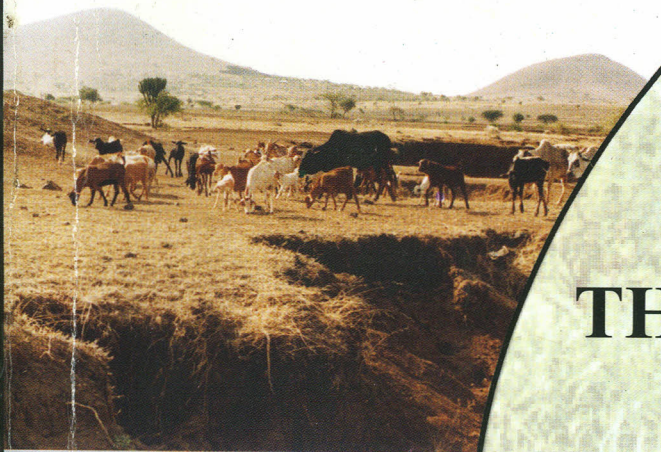


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THE ROLE OF PLANT RESIDUES IN SOIL PRODUCTIVITY: FARMERS' KNOWLEDGE AND PRACTICES IN EMBU DISTRICT, KENYA

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ABSTRACT

Plant residues from trees, crops or weeds play an important role in determining the soil fertility status in smallholder farmers of the central highlands of Kenya region. A study was conducted in Embu district of Kenya, located in the densely populated windward side of the south-eastern slopes of Mount Kenya, to document farmers knowledge and practices in the prevalence and utilisation of these residues. A total of 134 small-scale farmers cutting across five major agro-ecological zones of the 30 km transect were interviewed. Farmers indicated that trees, crops or weed residues found in their farms were associated with generation of plant residues which either improve or impoverish the farm niches where they are found. Plant residues that were associated with soil fertility enhancement included: *Zea mays*, *Physeolus vulgaris*, *Grevillea robusta*, *Combretum molle*, *Cordia africana*, *Ficus sycomorosa*, and *Camellina sinensis*. On the other hand, the residues of *Eucalyptus saligna*, *Macadamia integrifolia*, *Cupressus lusitanica*, *Croton megalocarpus*, *Acacia mearnsii*, *Sorghum bicolor* and *Mangifera indica* continued to impoverish the soil in the farm fields where they occur. The farmers attributed the good or poor crop performance in farm sections with certain types of plant residues to the decomposability

as well as the levels of crop nutrients contained in these residues. The implication of these farmers' perception on the farming patterns prevailing in this region were that there was a shift toward more cultivation of crop or trees species that were associated with soil fertility enhancement.

Key words: Smallholder farmers, farmers' knowledge, trees, crops, soil improvement, soil impoverishing, farm niches.

INTRODUCTION

Degraded soils are a major constraint to agricultural production and food security in the central highland of Kenya region (Smaling, 1997; Hudgens 1996). The traditional

Long term experiments provide some insights in the consequences of land management strategies that cannot be obtained through other means. For instance, trials established at Kenya Agricultural Research Institute land at Kabete near Nairobi have shown that the soil organic matter declined from 2.1% (in the original coffee estate) to 1.2% C after planting a maize-beans rotation over a period of twenty years (Kapkiyai *et al.*, 1999). Swift and Woome (1993) state that it is not the loss of the soil carbon which poses the threat to the smallholder livelihood, but rather the

associated decline in crop yields resulting from degraded soils. The use of plant residues play a crucial role in the long-term improvement of soil physical and chemical properties (Mugendi and Nair, 1997; Mureithi *et al.*, 1998).

Smallholder farmers in certain rural areas of world's poorer nations possess assets in the form of empirical knowledge of the individual knowledge of their ecosystems and changes that occur therein. They act as invaluable source of information that could be used to assess, monitor and evaluate changes that occur in land resources. (Brokensha, *et al.*; 1980; Pieri *et al.*, 1995). The indigenous knowledge systems, relative to modern science, are bodies of knowledge that develop as certain cultural or ethnic group strives to meet subsistence goals in a particular ecological setting. (Pawluk *et al.*, 1992). Zimmerer (1994) examined the relationship between local soil knowledge and science and concluded that the local knowledge is relatively accurate and an inexpensive means of monitoring soil conditions in a given environment. The local inhabitants are able to identify plant life and relate the vegetation with the rest of the ecosystem where they grow and also to give a detailed information of soil types and properties in the specific environment where they live (Brokensha, *et al.*, 1980; Steiner, 1998). The objectives of this study were therefore to; assess the soil fertility status of the smallholder farms as experienced by farmers, identify the major soil quality limitations affecting crop and livestock productivity in the study area as well as to identify the main plant residues that farmers have in their farms and the role these residues play in soil fertility enhancement.

MATERIALS AND METHODS

Sampling scheme

The study was conducted across an altitudinal gradient of the farming area of Embu district. The survey area consisted of a transect drive starting from mount Kenya forest edge, cutting across all the five major agro-ecological zones of the district, to the lower-most section at the Ena river which forms the Embu-Mbeere district boundary (Figure 1).

The survey route covered about 25 km passing through Rukuriri, Gitare, Runyenjes town, Gichiche and Ugweri shopping centres. The five major agro-ecological zones included in the study were Lower Highland (LH) 1, Upper Midland (UM) 1, Upper Midland (UM) 2, UM 3/4 as well as Lower Midland (LM) 3 (Jaetzold and Schmidt, 1983). The survey was carried out in July, which coincides with the middle of the growing season in this area, in order to be able to see the various reproductive stages of the various tree and weed species for easy identification. The survey commenced on July 3, 2002 and was completed on July 19, 2002. To select a representative sample of farmers in the study area a crude form of the area-frame-sampling procedure was used. Stratified random sampling was done and a total of 134 farmers (approximately 27 from each zone) were interviewed.

Data collection was done by administering a standard questionnaire to individual farmers (Plate 1). There was a farm visit during each of the interviews to different parts of the farm to observe the general characteristics of the farm, crops grown, livestock kept as well as the various types of weeds and crops in various farm niches. Information was sought on the interventions used to alleviate soil fertility problems and opinions on the role that plant residues could play in solving some of these problems.

EMBU DISTRICT MAP

Administrative Units

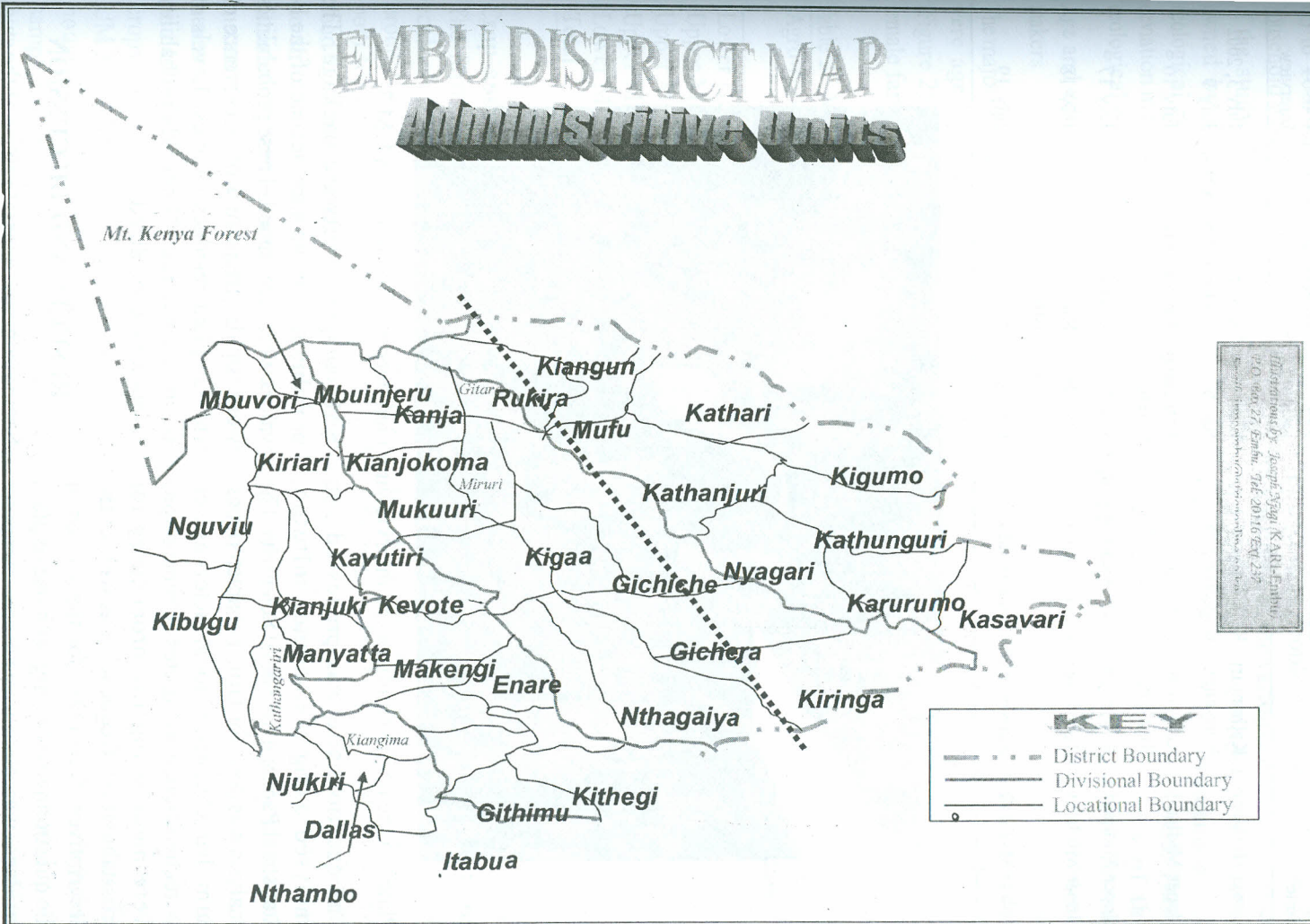


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Table 1. Summary of sampling scheme followed in selecting and interviewing farmers during the survey

Agro-Ecological Zone	Division	Location	Sub-location	Village	Date of Interview
Lower Highland 1	Kathanjuri	Kyeni north	Kiangungi	Kavururi	July 3, 2002
	Runyenjes	Kagaari north	Kanja	Gichegeni/Munyutu	July 9
Upper Midland 1	Kathanjuri	Kyeni north	Kiangungi	Kithangariri	July 10
	Runyenjes	Kagaari north	Gitare	Ngui	
Upper Midland 2	Runyenjes	Runyenjes township	Gichiche	Gaciari	July 17
Upper Midland 3/4	Runyenjes	Kagaari south	Gichiche	Kamisha	July 18
			Gichera	Ithatha	
Lower Midland 3	Runyenjes	Kagaari south	Kiringa	Nguruka	July 19



Plate 1. One of the enumerators interviewing members of a household in UM 3.

The questionnaire was processed and analysed using a computer software, Statistical Package for Social Scientists. The analysis was done for farmer characteristics, farm character, institutional factors as well as technological attributes. Comparisons were made using the procedures for crosstabulation, frequencies as well as the descriptives. Data entry for the section of the questionnaire dealing with use of plant residues, was done using Excel computer spread sheet program and then subjected to an analysis of variance (ANOVA) using the

SAS computer software package. The probabilities for the significance of the F-values were determined. These probabilities were for the frequency of occurrence of various plant residues sources. Levels of significance at the 1% and 5% probability levels were considered.

RESULTS AND DISCUSSION

Socio-economic characteristics of the study area

Farm sizes

Farm sizes in the study area ranged from 0.3 to 10.0 ha. The mean farm size per household was 3.0 ha (Table 2). The results of the study show that the size of land owned by farmers in different agro-ecological zones was almost similar. The deviation in the sizes across all the five agro-ecological zones was also wide.

Age and education level of farm decision makers

The majority of farm decision makers (95%) were aged between 31 to 60 years old (Figure 2) and consisted of both male and female farmers. The highest number of the

decision makers (30%) were people aged 41-50 years old. This therefore shows that most of the farm decision makers in the district were people with a good amount of experience in the various farming activities of their respective localities. Figure 3 shows the distribution of the respondents by the highest level of education attained. These results indicate that majority of the respondents (84%) had some formal education. About half of the respondents were people who had attained primary level of education. Only about a quarter of the respondents were people with secondary or tertiary education.

Table 2. Mean size of farms (ha) owned by farmers

Agro-ecological Zone	Mean	SD	Minimum	Maximum	Number of respondents
Lower Highland 1	3.0	2.2	0.4	7.0	26
Upper Midland 1	2.5	2.0	0.3	8.0	32
Upper Midland 2	2.8	1.8	0.8	7.0	21
Upper Midland ¾	3.0	1.9	0.7	7.0	27
Lower Midland 3	3.4	2.5	1.0	10.0	27
Total	3.0	2.2	0.3	10.0	133

Crop and livestock enterprises

The farm households in different agro-ecological zones were involved in the production of a wide range of enterprises both for cash, generation and provision of food to the household. There was, however, no strict criteria for the categorisation of farm enterprises as food or cash-based. For instance, certain crops such as maize and beans which were cultivated in the UM 1 and UM 2 agro-ecological zones as food crops were used in the warmer zones of UM 3 and LM 3 for cash generation in the households. Nearly all the households sampled had mixed type of farming where both crop and livestock enterprises co-exist within the farm. The main crop enterprises were maize, beans and coffee and were

found throughout the entire transect of the study area. Using the predominant crop enterprises in the respective zones as a basis for classifying the entire study area, five cropping zones were identified. These were; tea, tea-coffee, coffee, marginal coffee and maize/beans zones for the LH 1, UM 1, UM 2, UM ¾ and LM 3 agro-ecological zones, respectively.

Livestock farming was found to be an important farming enterprise in all the five agro-ecological zones of the district. The types of livestock kept by farmers include cattle, goats, sheep, pigs and poultry. On average, farmers in the district owned two herd of cattle and one goat. By contrast, ownership of pigs and sheep was not evenly

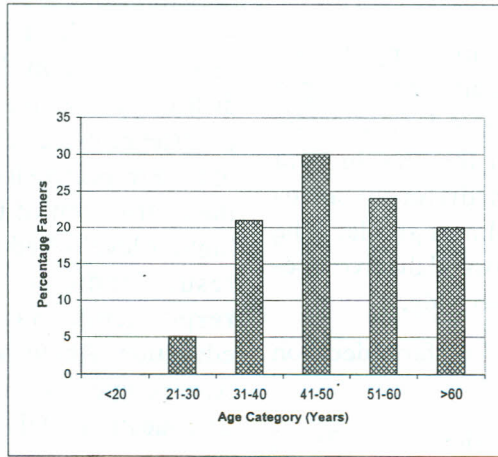


Figure 2. Distribution of farm decision makers by age groups

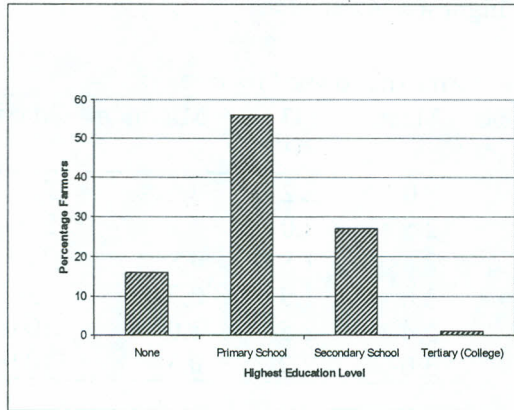


Figure 3. Distribution of respondents by highest education level attained

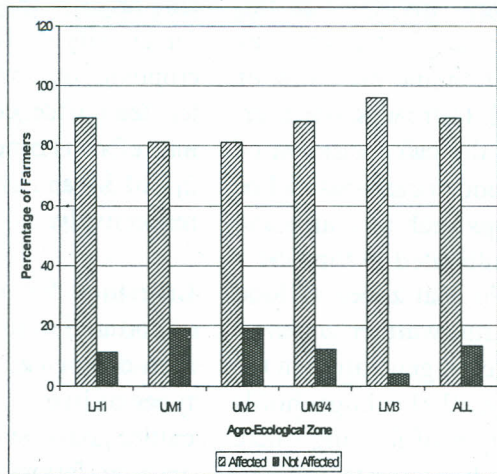


Figure 4. Proportion (%) of farmers affected by low soil fertility

distributed across the five agro-ecological zones. Poultry keeping was a widespread occupation in the entire district. The population of birds kept per household was, however, higher in the UM 2 as well as the UM 3/4 agro-ecological zones. The mean number of chicken per household was about 13. On average, each household in the district kept one type of livestock or another implying that mixed farming is the norm of the entire Embu district.

Soil fertility improvement resources

The main soil fertility management resources used by farmers included mineral fertilisers and animal manures. The types of inorganic fertilisers most commonly used by farmers included 20:20:0, 23:23:0, Diammonium phosphate (DAP), 17:17:0 and Calcium Ammonium Nitrate (C.A.N). Ouma *et al.*, (2002) conducted a survey to determine the fertilizer use patterns in Embu district and

concluded that about 88 per cent of the farmers in the district use basal fertilizer application while only 17 per cent top dress their maize. Thirty three per cent of the farmers were not applying any fertiliser to the maize crop. Farmers indicated that the use of animal manure was an important method in the soil fertility management in the farms. However, majority of the respondents could not specify the exact amounts used in different crop enterprises within their farms.

Causes of low soil infertility in farmers fields

Farmers in all the five agro-ecological zones were affected by low soil fertility. On average, 87 per cent of all the farmers in the district were affected by the problems of low soil fertility in their farms (Figure 4).

Table 3. Proportion (%) of land within different farm niches with infertile soil

Farm niche	Percent	Number of respondents
Steep slope (conserved)	9	12
Steep slope (non-conserved)	11	15
Far from homestead	34	46
Whole farm	11	15
None-specific	34	46
Total	100	134

Table 4. Causes of soil fertility as perceived by farmers (% of farmers affected)

Agro-ecological Zone	Causes of soil infertility						Mean per zone
	Soil erosion	Over cultivation	Soil Type	Little or no amendments	Type of trees in farm	Unknown	
Lower Highland 1	11	21	28	19	11	10	20
Upper midland 1	25	19	16	19	3	18	24
Upper midland 2	10	14	43	5	5	23	16
Upper midland 3/4	20	3	34	27	0	16	20
Lower highland 3	11	11	48	22	4	4	20
Total	16	13	31	19	5	16	100

Within the farm fields, different parts of the farm were affected differently by the problem of soil infertility. The proportion of land within different farm niches that had an infertile soil is shown in Table 3. Sections of the farm that were positioned away from the homestead were more infertile (34%)

when compared to those positioned nearer to the homestead. Farm niches that lie at the steep slopes also accounted for about 20 per cent of all the infertile sections of the respective farms.

The reasons that farmers perceive to be the main causes of low soil fertility are shown in Table 4. In the LH 1 agro-ecological zone, farmers listed, in order of importance, soil type (28%), over-cultivation (21%) and little or no use of amendments (19%) as the main causes of low soil fertility. In the UM 1 agro-ecological zone, farmers listed, in order of importance, soil erosion (25%), over-cultivation (19%) and little or no use of amendments (19%) as the main causes of soil infertility. The two villages of Kithangariri and Ngui that were sampled in UM 1 are situated in very steep slopes and this may have contributed to the ranking of soil erosion as a major cause of soil infertility in this zone. The inherently low soil fertility nature of soils found in the UM 2 and LM 3 agro-ecological zones was listed as the predominant factor accounting for 43 and 48 per cent, respectively, of all reasons why soils in these areas were infertile. In the UM 3/4 agro-ecological zones, the three main causes of low soil fertility were ranked as soil type (34%), little or no amendments (27%) and soil erosion (20%). A summary of the ranking of the various causes of soil infertility for all the five zones of the study area (Table 4) show that soil type (31%) and little or no use of soil amendments (19%) were the predominant factors contributing to low soil fertility status in Embu district. A nutrient monitoring study carried out in the district by Gitari *et al.*, (1999) identified nitrogen as the main element that is lost in large quantities in the smallholder farms. The major avenues of loss were identified as leaching, erosion and harvested crop products where -276, -143 and -85 kg ha⁻¹ N, respectively, were lost annually for all the five land use zones of the district combined.

The role of plant residues in soil fertility

Farmers listed several sources of plant residues that were found in their farms. They

also indicated whether the residues were known to enhance or impoverish soil fertility status.

Soil improving plant residues

There were three main sources of plant residues whose presence in the soil was beneficial. These sources included crops, trees and weeds. The frequency of prevalence in occurrence of soil improving plant residues is presented in Table 6.

The LH 1 agro-ecological zone had very few sources of plant residues. The main residue sources in this zone was either the tea bushes (*Camellina sinensis*) or *Grevillea robusta* trees. The rest of the agro-ecological zones had several alternative sources of these plant residues. *Grevillea robusta* was a main source of plant residues for soil fertility improvement in all the five agro-ecological zones. Three other sources of plant residues showed a frequency of prevalence in occurrence that was significantly higher ($P < 0.01$) than all the other residue sources. These three were; maize (*Zea mays*), beans (*Phaseolus vulgaris*) and *Grevillea robusta* tree leaves. Several researchers have investigated the usefulness of maize stover as a source of crop nutrients. The conclusion was that although the residues have a low content of lignin and polyphenol compounds (which govern the release of crop nutrients), the presence of high carbon: nitrogen ratio in these residues prolong the period when such released nutrients may be utilized by a growing crop (Ishutza, 1997; Msumali, 1992 and Nandwa, 1995). The frequency of prevalence in occurrence of all the other trees, crops or weeds sources of plant residues was not significantly different even at the 5% level of significance. Apart from *Grevillea*, three other tree species whose leavy residues were listed as soil improving were *Cordia africana*, *Persea americana* and *Ficus sycomorus*. These tree species

were recorded in at least three of all the five agro-ecological zones. The plant residues of both *Tithonia diversifolia* and *Camellina sinensis* were listed to be good

in soil improvement but their distribution was restricted to only two of the five agro-ecological zones (Table 6).

Table 6. Frequency of prevalence in occurrence of soil improving plant residues in different Agro-ecological zones

Plant residue source	Agro-ecological zone					Mean	Probability of Significance
	LH 1	UM 1	UM 2	UM 3/4	LM 3		
<i>Zea mays</i>	-	12	14	17	31	18 (2.4)*	0.0001
<i>Grevillea robusta</i>	9	11	9	8	2	8 (1.9)	0.001
<i>Phaseolus vulgaris</i>	-	12	11	6	6	9 (2.4)	0.002
<i>Persea americana</i>	-	4	4	4	3	4 (2.3)	0.13
<i>Vitex keniensis</i>	-	3	1	-	-	2 (3.3)	0.52
<i>Camellina sinensis</i>	2	5	-	-	-	4 (3.4)	0.31
<i>Galinsoga parviflora</i>	-	4	-	6	1	3 ((2.7)	0.22
<i>Ficus sycomorus</i>	-	3	4	7	-	5 (2.7)	0.11
<i>Cordia Africana</i>	-	1	5	5	-	3 (3.3)	0.41
<i>Tithonia diversifolia</i>	-	-	3	3	-	3 (3.3)	0.39

* Figures in brackets are standard errors of the respective means.

Table 7. Frequency of prevalence in occurrence of soil impoverishing plant residues in different Agro-ecological zones

Plant residue source	Agro-ecological zone					Mean	Probability of Significance
	LH 1	UM 1	UM 2	UM 3/4	LM 3		
<i>Macadamia integrifolia</i>	9	14	11	3	-	9 (1.6)*	0.0001
<i>tetraphylla</i> spp.							
<i>Cupressus lusitanica</i>	9	8	9	-	-	9 (1.9)	0.0002
<i>Eucalyptus saligna</i>	4	3	12	7	6	6 (1.4)	0.0003
<i>Grevillea robusta</i>	2	2	2	8	4	4 (4)	0.02
<i>Acacia mearnsii</i>	2	2	1	-	-	2 (1.9)	0.37
<i>Mangifera indica</i>	-	-	2	6	1	3 (1.9)	0.17
<i>Persea americana</i>	3	1	-	2	-	2 (1.9)	0.23
<i>Croton megalocarpus</i>	-	-	-	3	4	3 (1.9)	0.13
<i>Sorghum bicolor</i>	-	-	-	-	4	4 (3.4)	0.31

* Figures in brackets are standard errors of the respective means.

Soil impoverishing plant residues

Plant residues whose presence in the soil has none or a negative effect on soil fertility are shown in Table 6. Two of these tree species, *G. robusta* and *P. americana* were listed by many farmers as soil improving and by a few others as soil impoverishing. Most of the farmers who listed *Grevillea* as soil impoverishing were mainly in the lower agro-

ecological zones of UM 4 and LM 3. The frequency of prevalence in the occurrence of *Macadamia* spp., *Cupressus lusitanica* and *Eucalyptus saligna* were significantly different ($P < 0.01$) than all the other plant residue sources across all the five agro-ecological zones. Researchers such as Palm and Rowland, 1992 as well as Mugendi and Nair, 1997 have observed that the presence

of some organic compounds such as lignin and tannins in plant residues act as an impediment to fast decomposition of such plant materials. In the higher and cooler agro-ecological zones of LH 1 and UM 1, *Acacia mearnsii* was listed as a tree species whose residues are not associated with any soil fertility enhancing attributes. In the warmer areas of UM 4 and LM 3 zones, farmers identified the residues of *Croton megalocarpus* and *Sorghum bicolor* as sources of soil impoverishing residues. Other tree residues listed as soil impoverishing, although not with a significantly different ($P < 0.05$) frequency of occurrence, included *C. megalocarpus* and the mango fruit trees (*Mangifera indica*).

Reasons for good and poor crop performance under certain plant residues

Farmers attributed the ability of a certain plant residue to either enhance or impoverish the soil primarily due to the speed of decomposition of the respective residues. Eighty six per cent of the respondents attributed good crop performance to the fast rate of decomposition of these residues. The reasons behind the poor performance of crops in farm niches where certain plant residues were prevalent were given as the lack of these residues to decompose (56%), slow rate of decomposition (16%), as well as the inability of these residues to release any plant nutrients upon decomposition (6%).

The remainder of the farmers were not aware of any reasons behind the poor or good performance of crops under certain plant residues. These reasons given by the farmers corroborate well with those of researchers who have concluded that fast decomposing plant residues (primarily due to low carbon : nitrogen ratios as well as low levels of lignin and polyphenolic compounds) are important properties in determining the release of crop nutrient from such residues (Palm and Sanchez, 1991; Oglesby and Fowness, 1992).

Methods of increasing on-farm good performing plant residues

Most of the farmers interviewed (79%) appeared to have some knowledge of the occurrence of certain wild or domesticated plant species whose residues had a positive impact on soil fertility improvement. Farmers also listed certain methods that they could use to increase the amounts of good performing plant residues in their farms. About half of all the respondents (49%) indicated that they could increase the good performance residues by not removing any residues found in their farms for them to decompose *in situ*. Twenty per cent of the respondents considered the option of planting more land with such plant species as a feasible option (Table 5). Eighty seven per cent of the respondents indicated their willingness to introduce new soil improving plant species in their farms.

Table 5. Methods for farmers to increase plant residues on-farm

Method of increasing residues	Percent	Number of respondents
Leave existing residues in the farm	49	66
Plant more	20	34
Biomass transfer	17	23
Don't know	14	11

CONCLUSIONS AND WAY FORWARD

This study has established that smallholder farmers of Embu district, and the rest of the central highlands of Kenya region, are constrained by low soil productivity which they are aware of. Although the two prevalent soil fertility improvement resources (mineral fertilizers and animal manures) are not available in adequate quantities, farmers are aware of the usefulness of certain locally available plant residues that could play a crucial role in soil fertility enhancement. This study was meant to serve as an 'eye-opener' to researchers who could assist the farmers in identifying and classifying these plant residues using a more scientific approach to the issue. The residues could then be harnessed more effectively in soil fertility improvement at local level. Further, there exists a wide scope for the introduction of better quality plant residues with a bigger potential for soil fertility enhancement in these smallholder farms.

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