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# Participatory On-Farm Comparative Assessment of Organic and Conventional Farmers' Practices in Kenya

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## ABSTRACT

On-farm participatory research was carried out in low and high potential areas of Kenya to assess agronomic and socioeconomic viability of organic and conventional practices and their prospects at farm level. At each site, 20 farms participated in the study, divided equally between organic and conventional farming systems. Agro-economic study of current organic practices of growing maize using compost and liquid manure top dressing in low potential areas showed a significantly higher performance than those of current conventional farmers' practices of a combined application of manure and mineral fertilizers. Maize grain yields were 11–21% higher than those obtained with conventional practices. Net cash benefits, total net benefits and return to labour were also high. This, however, was the reverse of results obtained from high potential areas, where conventional practices outperformed organic practices in major agro-economic indicators. The study further revealed that current farmers' practices of combining compost and liquid manure had a potential of turning partial negative nitrogen balances into positive ones in low potential areas and making them less negative in high potential areas. This was in contrast to current conventional farmers' application rates of manure and mineral fertilizers. The partial phosphorus balances appeared rather balanced under conventional and organic practices and became more positive with nutrient additions through top dressing using mineral fertilizers and liquid manure. Despite these findings, large scale application of manure and compost are constrained by their availability and quality at farm level, while the use of mineral fertilizers is limited by their escalating costs.

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## INTRODUCTION

The last two decades have seen a decline in per capita food production in Kenya, as in many other countries in sub-Saharan Africa. It has been suggested that the use of high external input agriculture (HEIA) could help solve this problem. However, HEIA has been tried unsuccessfully among resource poor smallholder farmers who comprise 80% of Kenya's population. This is partly due to socioeconomic, biophysical and policy environments. Low economic returns to agricultural produce, existing market risks, and costs and difficulty of access to external inputs have hindered the economic efficiency of HEIA systems. Organic agriculture is currently being floated as an alternative approach towards attaining sustainable and productive agricultural systems, especially among smallholder farmers. Kariuki *et al.* (1994) and Scialabba (2000) have reported that conversion to organic agriculture has been triggered by economic self reliance, providing alternatives to decreased access to agricultural inputs, natural resource conservation, food self sufficiency, export promotion and rural and wider social development.

A number of NGOs have been particularly active in promoting organic agriculture in Kenya. Likewise, international institutions and government bodies are also increasingly showing interest in low external input and sustainable agriculture systems in general. However, despite these efforts, the performance of organic farming has rarely been examined systematically. Werf *et al.* (1997) and Onduru & Scialabba (2001) have reported that the few published comparative studies emanating from developing countries raise concerns regarding methodology and validity of results. This is in contrast to export-oriented farming systems from developed countries. Little is known about the comparative performance of organic and conventional farming systems in developing countries. Furthermore, understanding comparative performance of farming systems under different agroecological conditions and socioeconomic settings is a prerequisite for revealing opportunities to be exploited and hurdles to be overcome so as to increase productivity of farming systems.

This paper draws its strength from on-farm participatory research conducted in low and high potential areas of Kenya by Kenya Institute of Organic Farming (KIOF-non governmental organization) and Education Training Consultants (ETC-Netherlands). The focus of the study was on agro-economic performance of organic farming techniques and their conventional equivalents. KIOF and ETC-Netherlands then teamed up with Agricultural Economics Research Institute (LEI-DLO The Netherlands) to study agro-economic characteristics of compost production among other aspects. The programme expected that insights gained could be used in policy level discussions on potentials of organic farming. The objective of this paper is, thus, to provide insight into agro-economic performance, opportunities and limitations of organic farming for smallholder farmers in Kenya.

## MATERIALS AND METHODS

### Study sites

The study was conducted in low potential areas of Machakos District and high potential areas of Kirinyaga District of Kenya. In each district the villages chosen for the study were within the same catchment and thus were relatively uniform in moisture availability, temperature regime, soil fertility, topography, soil conservation status and other natural conditions.

Kirinyaga District is located in Central Province of Kenya and covers an area of about 112700 ha. It has a population of 455000 (CBS, 2000). The altitude ranges from 1090 to 2130 m towards Mount Kenya. Rainfall received in the district is bimodal, punctuated with intermittent rains between the long and short rains. The annual average rainfall ranges from 1000 to 1900 mm, depending on location and altitude. The research site has two growing seasons per year with a total length of 150–209 days. The soils in the study site are well-drained, extremely deep, dark reddish brown to brown, friable and slightly smeary clay with acid humic topsoil (nitosols and andosols). Agricultural production in the district is threatened by problems of nutrient mining, crop pests and diseases, high costs of farm inputs, decreasing per capita arable land and inadequate marketing infrastructure.

The farming system is dominated by tea and coffee as cash crops. Maize, beans and a variety of vegetables are grown as subsistence crops. Dairy farming is important in the research site and the cattle are kept under zero grazing. The farmland is terraced, especially land under coffee, while tea acts as a cover crop. Land holdings are under a freehold tenure system.

Machakos District is located in Eastern Province of Kenya. It covers an area of about 616300 ha of which 85% is classified as semi arid to arid. The District has a population of 915000 persons (CBS, 2000). In the centre of the district, hills of up to 2100 m rise above the surrounding plateau, which slopes from 1700 m above sea level in the west down to 700 m above sea level in the south east.

Rainfall is bi-modal with an average of 500–1500 mm, depending on location and altitude. The research site has two growing seasons per year lasting from 90 to 119 days. The soils are shallow and well drained, with topsoils of loamy sand to sandy loam in many places (ferralsol-haplic acrisols with luvisols and ferralsols). Previous work (Jaetzold & Schmidt, 1982; Kassam *et al.*, 1991) has shown that these soils are deficient in nitrogen, phosphorus and organic matter. Subsistence mixed farming with some degree of crop and livestock integration is practised. Farmland is held under a freehold tenure system. Crops grown include maize, pigeon peas, sorghum, beans and fruit trees. Indigenous breeds of cattle, goats, sheep and poultry are kept under a semi-free range system. The cattle and shoats are corralled overnight thus enabling farmers to collect manure.

Tiffen *et al.* (1994) reported that Soil and Water Conservation (SWC) measures are extensively practised in the district to conserve the fragile soils. These include terraces, mainly bench terraces in the steep slopes, cut off drains, stone lines, trash lines, addition of farm yard manure, and crop residue management, including mulching and use of cover crops. Problems faced in the district include declining soil fertility, decreasing per capita arable land, unpredictable and unreliable rainfall, poor productivity of livestock and limited use of agricultural inputs (DAO, 1996).

### **General approach**

The study focus was on agronomic and socioeconomic viability of organic and conventional practices and their prospects at farm level. The study limited itself to the most prominent techniques as practised under organic and conventional farming systems; these were compost and liquid manure as practised by organic farmers, and 'boma' manure and application of mineral fertilizers under conventional farming practices. As the research aimed at studying actual farmers' practices, interference with farmers normal way of working was avoided and, for each group of farmers' studied practices were standardized towards the way they were being practised by the majority of farmers in the study site and, not towards recommended practices. This was deemed necessary in order to create a benchmark for understanding strengths and weaknesses of the current practices. The study was carried out through on farm research under the KIOF/ETC project, 'Towards Organic Farming in Eastern Africa'. A further study on agro-economics of compost production was carried out under the LEINUTS project, 'Potentials of Low External Input Agriculture in Attaining Productive and Sustainable Land use in Kenya and Uganda', in low and high potential areas of Kenya.

### **Farm selection (Kirinyaga and Machakos District)**

Two groups of farmers, organic and conventional, were selected for study within each catchment. Organic farmers were defined as those who had been exposed to organic farming practices and, in particular, were practising compost and liquid manure technologies. Liquid manure is a top dressing product made from fermented, culturally accepted fresh livestock droppings in water. Conventional farmers were not practising these technologies. They were defined as those applying boma manure and mineral fertilizers for crop production.

Farms were selected after community meetings organized in each study site, i.e. representative catchments in each study district. The workshops were aimed

TABLE 1

Main characteristics of farms studied in low and high potential areas of Kenya.

Characteristics	Low potential areas		High potential areas	
	Organic	Conventional	Organic	Conventional
No. of farmers	12	12	11	8
Female farmers (%)	84	53	38	14.5
Labour resources (No. of adults)	2.2	1.5	2.6	2.4
Average land size (ha)	1.2	1.2	1.7	1.5
Average no. of cattle	3	3	1	1
Fraction of farm produce sold (%)	21	7	98	98
Years of experience with organic technologies	2	n.a.	2	n.a.
<b>Soils</b>				
Nitrogen (total) %	0.07		0.20	
Phosphorus (Olsen) (ppm)	1.68		1.90	

at discussing objectives of the project, creating ownership of the project and discussing criteria for participation. Criteria for participation included willingness to participate in the project and the size of production resources. These resources included land holding, labour resources and number of livestock. Other criteria for selection were market orientation and years of experience in practising the techniques to be studied. The latter was more important in organic farms as it ensured that the farmers had sufficient experience with the technique to practise it competently. At each site, a total of 20 farms were selected, divided equally between organic and conventional farming systems. However, more farms were selected per group to cater for dropouts. Organic farmers were selected in collaboration with a local NGO (Kenya Institute of Organic Farming) who had trained farmers in organic farming practices in the study sites.

Conventional farmers were selected in a similar process, in collaboration with the government extension agency in the study site. Farms were included after a follow up visit to individual farmers in which it was assured that the volunteer farmers understood the objectives of the research, met the selection criteria and were motivated enough to participate in the study. A great effort was made to guarantee that the farms selected not only represented the population they were chosen from but also that the two groups of farmers were as comparable as possible with limited internal diversity. Table 1 shows characteristics of farms studied. The table shows that the farming groups were comparable with respect to labour resources, size of arable holding, topography and the number of adult heads of cattle in each zone.

## Experimental design, data collection, analysis and evaluation

Experimental designs were discussed between farmers and researchers in a group meeting held in each site. Since the approach was to assess actual farmers' practices, the experimental design was kept as simple as possible. Plot sizes were 100 m<sup>2</sup> divided over two treatments per farm. For each practice or technology, only one level of treatment was studied. Standardized farmers' practices studied are shown in Tables 2 and 3 for low and high potential areas, respectively. Local measuring units were used in the study. However, quantities of inputs applied by farmers were later translated into metric units for ease of analysis. The quantities of inputs were measured inputs of the current farmers' application rates without external intervention. The research plots were laid out within a normal maize field fertilized in a similar way. The timing and carrying out of cultural practices were jointly agreed between farmers and researchers in a group discussion for each study area separately before the onset of trials.

A simple data collection record sheet was designed, field-tested and adjusted before the start of data collection exercise. Data collection was done jointly by farmers and the research team for four seasons in low potential areas and two seasons for high potential areas. Data collected were; (1) Inputs used (seeds, compost, manure, fertilizers) and their origin (on-farm, off-farm, collected or purchased), (2) Outputs obtained (maize grains and stover), (3) Labour

TABLE 2

Studied farmers' practices in low potential areas.

Organic	Conventional
All	All
Plot size 5 × 10 m <sup>2</sup>	Plot size 5 × 10 m <sup>2</sup>
Shallow tillage (10-15 cm)	Shallow tillage (10-15 cm)
T <sub>1Org., LPA</sub> 500g-tin compost per hole (20 t ha <sup>-1</sup> ) Planting with indigenous maize Spacing of maize 0.3 × 0.45 m	T <sub>3Conv., LPA</sub> 500g-tin manure per hole (17 t ha <sup>-1</sup> ) Use of 1.5 pinches, fertilizer per hole (85 kg ha <sup>-1</sup> (20-20-0)) Planting with indigenous maize Spacing of maize 0.3 × 0.45 m
T <sub>2Org., LPA</sub> 500g-tin compost per hole (20 t ha <sup>-1</sup> ) 1 cupful liquid manure per hole for top dressing (10 t ha <sup>-1</sup> ) Planting with indigenous maize Spacing of maize 0.3 × 0.45 m	T <sub>4Conv., LPA</sub> 500g-tin manure per hole (17 t ha <sup>-1</sup> ) Use of 1.5 pinches fertilizer per hole (85 kg ha <sup>-1</sup> (20-20-0)) Use of 1.5 pinches top-dressing fertilizer per hole (78 kg ha <sup>-1</sup> (CAN, 26%N)) Planting with indigenous maize Spacing of maize 0.3 × 0.45 m

Key: Org. = Organic; Conv. = Conventional; LPA = Low potential areas

Quantities of inputs in metric units were obtained by measuring farmers' current practices.

requirements for different activities (land preparation, manuring/fertilization, planting, weeding, pest control, harvesting and others), gender and origin of labour (on-farm or hired), aspects of crop development (number of plants per plot, average crop height, pest and disease attack), (4) Quality of inputs and outputs, Extraction for N, P and K determination in inputs and outputs was performed as described by Novozamsky *et al.* (1983). After extraction, K was determined with a flame emission spectrometer, and P (Shouwenburg *et al.*, 1967) and N (Novozamsky *et al.*, 1974) were determined using colorimetric methods.

Data processing and analysis comprised farmers' evaluation and researchers' evaluation. Each season of research was concluded by a farmers' field day and evaluation when crops were still in the field and after harvest. Separate meetings were organized for low and high potential areas to share research results with farmers and extension staff at the end of each season. These meetings were meant to jointly reflect upon research experiences, evaluate performance of current practices and identify alternatives for their improvement. At the end of the period of study in both high and low potential areas, individual farmers perceptions on the outcome of the trials were further solicited through the use of a questionnaire.

TABLE 3

Studied farmers' practices in high potential areas.

Organic	Conventional
All	All
Plot size $5 \times 10 \text{ m}^2$	Plot size $5 \times 10 \text{ m}^2$
Shallow tillage (10-15 cm)	Shallow tillage (10-15 cm)
$T_{1\text{Org., HPA}}$	$T_{3\text{Conv., HPA}}$
500g-tin compost per hole ( $16 \text{ t ha}^{-1}$ )	500g-tin manure per hole ( $15 \text{ t ha}^{-1}$ )
Planting with hybrid maize (H614)	Use of basal fertilizer- Mixture of 25-5-5 + 5 S
Spacing of maize $0.3 \times 0.60 \text{ m}$	( $270 \text{ kg ha}^{-1}$ ) and 23-23-0 ( $200 \text{ kg ha}^{-1}$ )
	fertilizers in the ratio of 1.4:1 (four pitches per hole)
	Planting with hybrid maize (H614)
	Spacing of maize $0.3 \times 0.60 \text{ m}$
$T_{2\text{Org., HPA}}$	$T_{4\text{Conv., HPA}}$
500g-tin compost per hole ( $16 \text{ t ha}^{-1}$ )	500g-tin manure per hole ( $15 \text{ t ha}^{-1}$ )
1 cupful liquid manure per hole for top dressing ( $20 \text{ t ha}^{-1}$ liquid manure)	Use of basal fertilizer- Mixture of 25-5-5 + 5 S
Planting with maize H614	( $270 \text{ kg ha}^{-1}$ ) and 23-23-0 ( $200 \text{ kg ha}^{-1}$ )
Spacing of maize $0.3 \times 0.60 \text{ m}$	fertilizers in the ratio of 1.4:1 (four pinches per hole)
	Top dressing 25-5-5 + 5S ( $200 \text{ kg ha}^{-1}$ )
	Planting with indigenous maize
	Spacing of maize $0.3 \times 0.60 \text{ m}$

Key: Org. = Organic; Conv. = Conventional; HPA = High potential areas.

Quantities of inputs in metric units were obtained by measuring farmers' current practices.



## RESULTS AND DISCUSSION

### Compost production and use

The results of the agro-economic study of compost production in low and high potential areas of Kenya are shown in Table 4. While farmers in high potential areas mainly relied on boma manure mixed with bedding, for making compost, farmers in low potential areas mixed the little manure available with plant materials for making compost. In both sites, topsoil was added to other materials in layers. Pit composting was used.

Nutrient concentration of composts in low and high potential areas of Kenya were low as they fall below critical nitrogen content of 1.8–2% and may immobilize nitrogen temporarily (Sanchez *et al.*, 1997). Previous work (Dalzell *et al.*, 1979; Müller-Sämann & Kotschi, 1994) has shown that nitrogen concentration of compost ranges from 0.34 to 1.1% while potassium concentration ranges from 0.4 to 1.2%. Phosphorus has been reported to be in the range 0.2–0.9%.

Table 4 further shows that compost produced in the low potential area had a low quality compared with that from high potential areas. Under the zero-grazing system of raising cattle in high potential areas, manure is mixed with urine-soaked vegetation applied as cattle bedding. Between 40 and 60% of manure nitrogen is lost from kraals when bedding materials are not used (Saleem, 1998). The usefulness of bedding materials has been further underscored by Nzuma & Murwira (2000), who reported that the use of crop residues as bedding reduces ammonia loss from cattle kraals by 80% at farm level. They further found that three parts straw to 25 parts manure reduces ammonia loss by 85 and 50% from cow dung, and a mixture of cow dung and urine, respectively, under laboratory conditions. Thus the quality of inputs used for composting and their origin can partly explain the differences in compost quality found in low and high potential areas.

Compost preparation and storage methods also have an influence on nutrient concentrations. The pit composting method used in the study allowed materials to decompose under partial anaerobic conditions (materials in the pit) as well as partial aerobic conditions (materials laid above the pit surface). Storing and decomposing manure under anaerobic conditions increases its total nitrogen content. Musa (1975) reported that storing and decomposing manure in deep pits results in six times as much nitrogen as manure stored above ground after a period of four months of storage. Similar findings have been reported by Nzuma & Murwira (2000), who found that total nitrogen concentration of manure stored in pits increased gradually with time, reaching three times the concentration of manure from heaps without added crop residues in a period of 4–6 months. However, Sedogo *et al.*, (1989) have reported that

aerobic composting of sorghum straw, results in better quality compost (higher K, Ca, Mg, P and N content) than one resulting from anaerobic composting.

Although the beneficial effects of compost manure on soil biophysical properties have been documented (Müller-Sämann & Kotschi, 1994; Oduor & Klingspur, 1994), the labour required for making and utilizing compost is often considered a serious limitation. Table 4 reveals that labour for producing 1 t of compost was slightly less than that reported by Howard (1943) and Dalzell *et al.* (1979) who both came up with 3 labour days. Remonde *et al.* (1992) reported that making 1–1.5 t of compost required 4 labour days while Sturmheit (1985) found that production of 1 t of compost required 2–3 labour days.

Table 5 presents cost of nutrient contents of compost and that of mineral fertilizers used by farmers in the study. The retail market price for fertilizer was used to calculate the cost of each major nutrient (nitrogen, phosphorus and potassium). In valuing the cost of compost (Table 4), opportunity cost of manure, vegetation materials and maize stover were considered in low potential areas. These materials were not traded in the research site. In high potential areas, farmers' own manure was considered and valued at opportunity cost. Wood ash and water were valued at labour required to collect them. The nutrient concentrations of manure used in low potential area were 0.39% N, 0.10% P and 0.63% K. In high potential areas, manure had 0.77% N, 0.19% P and 0.60% K. From Table 5, the cost of nitrogen from organic sources (compost and manure) compared favourably with that of nitrogen derived from mineral fertilizers in low and high potential areas. However, nitrogen derived from fertilizer, 25-5-5-5S was more expensive. At all sites, the phosphorus from organic sources was more expensive than that from mineral fertilizers. This is attributed to the low phosphorus contents of manure and compost. Supplying potassium from organic sources was cheaper than that from mineral fertilizers.

At the study sites, farmers value cash expenditure as more costly than non-cash costs. The cost of compost, manure and the resulting nutrient costs were non-cash costs. Furthermore, many of the small-scale resource poor farmers who participated in the study in low potential areas did not have enough cash to purchase fertilizers nor were they growing cash crops like tea or coffee to generate cash, as was the case in the high potential areas. In the high potential areas, fertilizers were provided through credit from coffee co-operative societies or from the Kenya Tea Development Authority.

Although the above comparison between organic and inorganic fertilizers has been made on a nutrient basis, it needs to borne in mind that composition of composts vary widely depending on the raw materials used. Also, compost usually provides a wide range of micronutrients and nutrients are released more slowly from composts than from soluble inorganic fertilizers.

TABLE 4

Agro-economic characteristics of making 1 t of compost in Kenya (average of two seasons).

Materials	Low potential areas		High potential areas	
	Quantity (kg)	Cost (Ksh)	Quantity (kg)	Cost (Ksh)
Cattle manure	358	215	1055	1477
Wood ash	23	3	12	< 1
Water	217	21	45	< 1
Maize stalks	179	304	0	0
Green vegetation	272	182	0	0
Nutrient concentrations of compost				
N (%)	0.37		0.76	
P (%)	0.08		0.22	
K (%)	0.46		0.56	
Labour (person hours; Female labour percentage involvement in brackets)				
Pit digging	AM	1.6	16	1.0
	AF	0.2	2	0.1
Collection of materials	AM	1.6	16	1.2
	AF	2.2	22	0.6
Setting up heap	AM	1.2	12	3.7
	AF	1.1	11	1.1
	HL	0	0	0.3
Turning heap	AM	3.0	30	4.7*
	AF	0.4	4	2.1
	HL	0	0	0.4
Total labour for making 1 t compost	11.3 (35%)	113	14.5 (27%)	137
	(2.2 labour days)		(2.1 labour days)	
Total cost of 1 t of compost (Ksh)		838	1614	

\*Compost turned two times during decomposition.

Key: AM= adult male; AF = adult female; HL = hired labour; Ksh 60 = 1 US\$.

TABLE 5

Cost of nutrients in compost, manure and mineral fertilizers used by farmers in the study.

Nutrient source	Cost of nutrients (KSh kg <sup>-1</sup> )*					
	Low potential areas			High potential areas		
	N	P	K	N	P	K
Compost	76	349	61	71	245	93
Manure (own)	51	200	32	61	246	78
Fertilizer, 25-5-5 + 5 S	na	na	na	155	68	645
Fertilizer, 23-23-0	na	na	na	50	22	0
Fertilizer, 20-20-0	63	28	0	na	na	na
Fertilizer, CAN (26% N)	77	0	0	69	0	0

\*KSh60 = US\$1 at time of study.

### **Impacts of farmers' practices on labour demand**

The labour demand for farmers' practices in low and high potential areas are presented in Table 6, while the returns to labour are presented in Table 7. Table 6 shows that total labour demand for growing maize using compost was comparable to that of using a combination of manure and mineral fertilizers for non top-dressed plots ( $T_{1\text{Org.}}$  and  $T_{3\text{Conv.}}$ ). However, top dressing using liquid manure (organic practice) increased labour demand more than top dressing using mineral fertilizers (conventional practices) in both study sites. Indications show that the adoption of such labour intensive practices is not constrained by the high labour demand in the study sites, as food production is the main occupation of the farming families. Labour costs are cheap due to prevailing unemployment and farmers consider the use of family labour to be having no direct cash outlay. In both study sites family labour was the predominant source of labour for farm operations.

### **Agro-economic performance of farmers' practices in low potential areas**

Maize grain yields attained under farmers' practices are presented in Tables 7 and 8. In low potential areas, the maize grain yields under organic farmers' practices and those under conventional practices were not significantly different. Werf & De Jager (1993) reported similar results in India. The maize grain yields attained by the indigenous maize varieties planted by the farmers were comparable to the average yield of Katumani composite recommended for the area. Katumani composite has a yield potential of  $2700 \text{ kg ha}^{-1}$  (Anon., 1994). At the study site, top dressing using either liquid manure (organic farmers) or calcium ammonium nitrate (26% N, conventional farmers) resulted in yield increase, with the latter top dressing method giving better results (Table 8). These results indicate that nitrogen may be one of the limiting nutrients for maize production in the study area.

Even though conventional farmers supplied more nutrients for maize production than the organic farmers in low potential areas did, organic farmers still attained higher grain yields. This is may be explained by other effects that organic matter has on the soil properties. Soils in the study site are deficient in organic matter. Soil organic matter ameliorates nutrient supply, detoxifies harmful soil constituents, facilitates moisture and nutrient retention and has a role in improving soil structure. Therefore, a decline in soil organic matter is often associated with decreased yields, even when large amounts of external inputs are applied to the system (Woomer & Muchena, 1993). It has further been reported that there is no bonus gained in terms of increased fertilizer nitrogen efficiency by mixing mineral and organic inputs at moderate rates. Only when

TABLE 6  
Labour demand for farmers' practices<sup>a</sup> in low and high potential areas of Kenya.

	Low potential areas				High potential areas			
	Organic		Conventional		Organic		Conventional	
	T <sub>1Org.</sub> HPA	T <sub>2Org.</sub> HPA	T <sub>3Conv.</sub> HPA	T <sub>4Conv.</sub> HPA	T <sub>1Org.</sub> HPA	T <sub>2Org.</sub> HPA	T <sub>3Conv.</sub> HPA	T <sub>4Conv.</sub> HPA
Labour days ha <sup>-1</sup>	119.3	147.3	124.5	128.8	102.5	124.0	103.5	121.0
Increase (%)	23.5		3.4		21.0		16.9	

<sup>a</sup>See Tables 2 and 3 for details of practices.

TABLE 7

Agro-economic performance of farmers' practices (non top-dressed plots;  
CV % in parentheses).

Site	Parameter	Organic (T <sub>1Org.</sub> )	Conventional (T <sub>3Conv.</sub> )
Low potential areas	Grain yields (kg ha <sup>-1</sup> )	2449 (31)	2019 (36)
	Total net benefit (Ksh ha <sup>-1</sup> )	11597* (63)	5517 (126)
	Net cash benefit (Ksh ha <sup>-1</sup> )	23560* (31)	16991 (42)
	Return to labour (Ksh ha <sup>-1</sup> )	138* (40)	94 (53)
High potential areas	Grain yields (kg ha <sup>-1</sup> )	5071 (44)	8331* (35)
	Total net benefit (Ksh ha <sup>-1</sup> )	21981 (114)	46129 (70)
	Net cash benefit (Ksh ha <sup>-1</sup> )	50019 (51)	70110 (42)
	Return to capital (Ksh ha <sup>-1</sup> )	16* (54)	8 (36)
	Return to labour (Ksh ha <sup>-1</sup> )	229 (101)	510* (64)

\*See Tables 2 and 3 for details of practices.

\*Significant (ANOVA;  $p < 0.05$ ); Formulae for calculating economic indicators are presented in Table 9.

Quantities of inputs in metric units were obtained by measuring farmers' current practices.

sufficient organic materials have been added to have significant effects on soil structure, nutrient retention and root penetration is there likely to be increased efficiency in the use of mineral fertilizers (Palm *et al.* 1997). Müller-Sämann & Kotschi (1994) reported that organic matter improves soil structure. Similarly, Arakeri *et al.* (1962), Dalzell *et al.* (1979) and Flaig (1975) reported that addition of organic matter and/or humus increases biological activity of soil, improves water holding capacity and crumb formation, improves infiltration, protects soil against erosion, and facilitates the spread and penetration of plant roots.

Materials with a high C/N ratio will temporarily fix N or P in the soil inhibiting subsequent plant growth. Well-composted materials have a low C/N ratio. Heathcote (1969) and Tanaka (1974) reported that trace element deficiencies, which often develop after several years of mineral fertilizer application, are less likely when compost is used.

TABLE 8

Impacts of different top dressing practices on maize grain performance in Kenya  
(CV% parentheses).

	Low potential areas		High potential areas	
	Organic	Conventional	Organic	Conventional
A: Non top dressed (kg ha <sup>-1</sup> )	2449 (31)	2019 (36)	5071 (44)	8331 (35)
B: Top dressed (kg ha <sup>-1</sup> )	3111 (30)	2805 (43)	6274 (42)	9700 (32)
Marginal yield increase (A-B) (%)	27	39	24	16

TABLE 9

Description of economic indicators used.

Cash Benefits (CB)	Total output valued at market prices of output actually sold.
Non Cash Benefits (NCB)	Total output valued at market prices of output actually home consumed.
Total Benefits (TB)	Total output valued at market prices (including outputs actually sold and home consumed). TB is equivalent to gross income: $TB = CB + NCB$ .
Cash Costs (CC)	Cash expenditures (external input expenses).
Non Cash Costs (NCC)	Valued internal inputs (e.g. compost, family labour, etc.).
Total Costs (TC)	TC is equivalent to Cash Costs plus Non Cash Costs: $TC = CC + NCC$
Total Net Benefits (TNB)	TNB is equivalent to Total Benefits minus Total Costs: $TNB = TB - TC$ . TNB is often referred to as gross margin.
Net Cash Benefits (NCB)	NCB is equivalent to Cash Benefits minus Cash Costs: $NCB = CB - CC$ . NCB is equivalent to Net Cash Income.
Return to Capital	Is equivalent to Cash Benefits divided by Cash Costs: $= CB : CC$
Family Labour Days (FLD)	Is equivalent to the number of hours used by the family for a certain technical topic divided by: • 5 for MPA; • 7 for HPA.
Family Labour Costs (FLC)	Is equivalent to the number of family labour days valued at pay rate of labourers for a certain technical topic (inclusive of all labour carried out to accomplish the respective topic).
Return per Family Labour Day	$= TNB : FLD$ $= (TB - TC) : FLD$ $= (TB - CC - NCC) : FLD$

Table 7 further reveals that current farmers' practices under organic farming system in low potential areas resulted in better economic performance than did those of their conventional counterparts. Total net benefits, net cash benefits and return to labour were significantly higher than those observed from current conventional practices. Return to labour was approximately twice the opportunity cost of labour in the research site. Descriptions of economic indicators are presented in Table 9.

### Agro-economic performance of farmers' practices in high potential areas

In high potential areas, conventional farmers' practices resulted in higher maize grain yields than in organic farms (Table 7). Similarly, economic performances of conventional practices were higher for all major economic parameters except for return to capital (Table 8). Organic farmers used less cash input costs than their conventional counterparts. The higher performance in high potential areas

can be explained by the effects of combining organic materials with mineral fertilizers in conditions of high rainfall. During the study period, 1195 and 455 mm of rain were received in high and low potential areas, respectively. The efficacy of fertilizer use is increased in adequate moisture conditions. The nutrients supplied by the addition of organics are additive to those supplied by inorganic sources. Added benefits of combined nutrient additions are probably more related to the quality of the carbon substrate of the organic material and its effects on nutrient availability (Palm *et al.*, 1997).

## Nutrient balances

Nutrient balances for farmers' practices are presented in Table 10. The table shows that partial N balances were negative for non-top dressed plots ( $T_{1\text{Org., LPA}}$  and  $T_{1\text{Org., HPA}}$ ) for organic farming practices in low and high potential areas. This was also true for conventional practices ( $T_{3\text{Conv., LPA}}$  and  $T_{3\text{Conv., HPA}}$ ). De Jager *et al.* (2001) reported similar results for maize with nutrient outputs exceeding inputs by 53–56 kg N ha<sup>-1</sup> yr<sup>-1</sup>.

With increased nitrogen application through top dressing using liquid manure, the net negative nitrogen balances were turned positive in low potential areas and became less negative in high potential areas. However, mineral top dressing fertilizer, at the current rates of application, was insufficient to turn the net negative N balances into positive in both low and high potential areas. Furthermore, it was observed that N balance was not improved under top dressing practice at farmers' current rates of mineral fertilizer application in high potential areas. The high grain yields and crop by-products attained under this fertilization method mined nutrients from the system, thus the nitrogen balance

TABLE 10

Nitrogen and phosphorus balances under farmers' practices<sup>a</sup> in Kenya.

Nutrient balance (kg ha <sup>-1</sup> yr <sup>-1</sup> )				
Low potential areas	$T_{1\text{Org., HPA}}$	$T_{2\text{Org., HPA}}$	$T_{3\text{Conv., HPA}}$	$T_{4\text{Conv., HPA}}$
Partial N balance	-50	+18	-21	-30
Partial P balance	+7	+17	+13	+28
High potential areas	$T_{1\text{Org., HPA}}$	$T_{2\text{Org., HPA}}$	$T_{3\text{Conv., HPA}}$	$T_{4\text{Conv., HPA}}$
Partial N balance	-120	-13	-129	-159
Partial P balance	-4	+6	+25	+16

<sup>a</sup>See Tables 2 and 3 for details of practices.

Quantities of inputs in metric units were obtained by measuring farmers' current practices.



was still negative. The farmers' practices for maize cultivation depleted more nitrogen than phosphorus. Partial phosphorus balances appeared positive. However, in organic and conventional farming systems, phosphorus balance generally improved through the use of top dressing fertilizers (liquid manure and mineral fertilizers).

### Farmers' perceptions on the current practices

Farmers' perception on their practices is presented in Table 11. The table shows that each group of farmers preferred their own fertilization method. Organic farmers' preferred using compost while conventional farmers preferred using manure and/or fertilizers. Farmers' criterion for selecting a given fertilization method was mainly based on yield level. Farmers reported advantages of using boma manure as being the fact that its effects last for more than one season, it improves soil structure and texture and it is locally available and cheap (no cash demand). It was further mentioned as being bulky and does not stimulate fast crop growth compared with mineral fertilizers. Compost was perceived to be cheap and locally available, improves soil structure and its use results in high yield over time. The disadvantages were mentioned as the fact that it is labour intensive to make and apply (bulky) and its preparation is hindered by insufficient availability of materials. Farmers mentioned three main advantages of using mineral fertilizers (basal and top dressing fertilizers) as being the fact that it is easy to apply, stimulates fast growth of crops and it is required in small quantities. The disadvantages were mentioned that it is expensive to apply, it needs to be applied every season for better results, burns crops when rains fail and its continual use affects soil water moisture retention (destroys soil structure).

TABLE 11

Farmers' preferences for different fertilization methods for maize cultivation in Kenya (number of female farmers in parentheses).

Method	Low potential area		High potential area	
	Organic (n = 12)	Conventional (n = 12)	Organic (n = 11)	Conventional (n = 4)
Fertilizers only	0 (0)	4 (2)	0 (0)	4 (2)
Manure only	1 (0)	6 (3)	1 (0)	0 (0)
Compost only	7 (7)	0 (0)	10 (5)	0 (0)
Manure + fertilizers	1 (1)	0 (0)	0 (0)	0 (0)
Compost + fertilizers	0 (0)	0 (0)	0 (0)	0 (0)
Manure + compost	0 (0)	1 (0)	0 (0)	0 (0)
Any other	0 (0)	0 (0)	0 (0)	0 (0)

Farmers mentioned three main advantages of using liquid manure as being the fact that liquid manure improves crop yields, makes crops healthy, and it is cheap and locally available. The disadvantages of using liquid manure were mentioned as high labour demand for preparation and unavailability of sufficient containers for preparation. Farmers' criteria for choosing any top dressing method, in order of priority, were based on the effects of the top-dressing method on yields, plant health and rate of crop growth. They further mentioned cost, availability and ease of application as other criteria to consider.

## CONCLUSIONS

It is often said that the potential of organic farming techniques in the tropics is high for high potential areas, but limited for low potential areas. However, this study has shown that organic farming practices are equally competitive in low agricultural potential areas. The application of organic techniques of compost and liquid manure in organic matter deficient soils of low potential areas resulted in significantly higher agro-economic performance of maize than the current use of combined application of limited manure and mineral fertilizers under conventional farming systems. Maize grain yields and major economic indicators such as net cash benefits, total net benefits and return to capital were significantly higher under the organic farming system. However, this situation was the reverse for high potential areas where the combined application of manure and mineral fertilizers attained high performance. The additive effects of nutrients supplied through organic and inorganic sources were more pronounced under high soil moisture conditions found in high potential areas.

Assessment of labour demand for a technology is important for evaluating its importance. From the study it can be concluded that labour demand for producing 1 t of compost is 2 labour days. However, other studies have shown that this figure can go up to 4 labour days. The results of this study has further shown that total labour required for growing maize using organic farming practices was not significantly different from that of using conventional practices in low and high potential areas of Kenya. However, labour for making compost and liquid manure increases labour demand substantially above that required to practise conventional techniques. Top dressing liquid manure increased total labour demand by 21–24%. This figure was 3–17% for the use of Calcium Ammonium Nitrate (CAN). However, this demand in labour may not impede the adoption of organic farming as the study has shown that organic farming practices realized two or three times higher rate of return to labour than prevailing opportunity cost of labour in low and high potential areas. The study has further shown that farm families value cash costs more highly than non-cash costs and that mainly family labour (viewed as non-cash costs) is used in the study sites. Agricultural production is also perceived as a basic essential for securing food for the family.

Analysis of inputs, such as compost (organic systems) and manure (conventional system) used for producing maize in organic and conventional farming systems revealed that they were of low quality with nitrogen contents falling below the critical levels of 1.8–2%. Thus strategies to increase agricultural production in these study sites would require improvement in the quality of these inputs in addition to exploring other opportunities for soil fertility management. Maximizing internal nutrient sources while optimizing the use of low cost external inputs within the context of integrated soil fertility management would be a plausible way forward. However, this requires conscious, demand driven and judicious investment in the socioeconomic and biophysical environments within which soil fertility management takes place.

The results of nutrient balances showed that a combination of compost and liquid manure turned net negative partial nitrogen balances into positive, at the current rates of application in the low potential areas and, although still negative, improved partial nitrogen balance in the high potential areas. Conventional farmers' levels of applications of manure and mineral fertilizers did not significantly improve the partial negative nitrogen balance in both low and high potential areas. The high grain yields and crop by-products attained under conventional fertilization in high potential areas, mined nitrogen from the system. The farmers' practices for maize cultivation depleted more nitrogen than phosphorus. Partial phosphorus balances appeared rather positive. However in organic and conventional farming systems, phosphorus balances improved through the use of top dressing fertilizers (liquid manure and mineral fertilizers).

The study has further shown that integrating farmers' evaluation and perceptions can result in better insight into the opportunities and limitations of farm practices under study. Farmers' evaluation of the advantages and disadvantages of compost, liquid manure and mineral fertilizers and the technical and socioeconomic constraints in their use can improve the focus of future research and development activities.

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## References

- Anon. (1994). Focus on Kenya Agricultural Research Institute (KARI). KARI's recommendations for maize growing in Kenya. *Daily Nation*, 15 February 1994.

- Arakeri, H.R., Chalam, G.V., Satyanarayana, P. & Donahue, R.L. (1962). *Soil Management in India*. Asia Publishing House; Bombay, India.
- CBS (Central Bureau of Statistics) (2000). *Kenya Population Census, Interim Report*. Ministry of Planning and National Development, Government of Kenya; Nairobi, Kenya.
- Dalzell, H.W., Gray, K.R. & Biddlestone, A.J. (1979). *Composting in Tropical Agriculture*. Review Paper No. 2. The International Institute of Biological Husbandry; Ipswich, U.K.
- DAO (1996). *District Annual Report, Machakos District*. Draft report.
- De Jager, A., Onduru, D.D., Wijk, M.S., van Vlaming, J. & Gachini, G.N. (2001). Assessing sustainability of low-external-input farm management systems with the nutrient monitoring approach: a case study in Kenya. *Agricultural Systems*, **69**, 99–118.
- Flaig, W. (1975). Specific effects of soil organic matter on the potential of soil productivity. *FAO Soils Bulletin*, **27**, 31–70.
- Heathcote, R.G. (1969). Soil fertility under continuous cultivation in Northern Nigeria. *Experimental Agriculture*, **6**, 229–237.
- Howard, A. (1943). *An Agricultural Testament*. Oxford University Press: New York, U.S.A. and London, U.K.
- Jaetzold, R. & Schmidt, H. (1982). *Farm Management Handbook of Kenya. Vol. 2 Natural Conditions and Farm Management Information*. Ministry of Agriculture; Nairobi, Kenya.
- Kariuki, J., Onduru, D.D. & Muchoki, M. (1994). *Organic Farming Adoption Survey*. KIOF/IDRC; Nairobi, Kenya.
- Kassam, A.H., Velthuisen, H.T., Fischer, G.W. & Shah, M.M. (1991). *Agro-Ecological Land Resources Assessment for Agricultural Development Planning. A Case Study of Kenya. Resources Database and Land Productivity. Technical Annex 1. Land Resources*. Land and Water Development Division; FAO and IIASA.
- Müller-Sämann, K.M. & Kotschi, J. (1994). *Sustaining Growth—Soil Fertility Management in Tropical Smallholdings*. CTA-GTZ, Margraf Verlag; Weikersheim, Germany.
- Musa, M.M. (1975). Organic materials as fertilizers. In *Organic Materials as Fertilizers*. FAO, *Soils Bulletin No. 27*. pp. 89–95. FAO; Rome, Italy.
- Novozamsky, I., Eck, R. van, Shouwenburg, J. Ch. van & Walinga, I. (1974). Total nitrogen determination in plant material by means of the indolephenol blue method. *Netherlands Journal of Agricultural Science*, **22**, 3–5.
- Novozamsky, I., Houba, V.J.G., Erick, R. van & Vark, W. van (1983). A novel digestion technique for multi-element plant analysis. *Communication in Soil Science and Plant Analysis*, **14**, 239–249.
- Nzuma, J.K. & Murwira, H.K. (2000). *Improving the Management of Manure in Zimbabwe. Managing Africa's Soils No 15*. International Institute for Environment and Development, Dry Lands Programme; London, U.K.
- Oduor, A. & Klingspur, P. (1944). *Organic Natural Supply for Maize and Beans*. A paper presented at Watakatifu Wote Centre, Catholic Diocese, Ngong, Kenya. Department of Agriculture Engineering, University of Nairobi; Nairobi, Kenya.
- Onduru, D.D. & Scialabba, N. (2001). *Methodology for Comparative Studies: Organic, Conventional and Traditional Farming Systems in Low Potential Areas*. KIOF/FAO; Nairobi, Kenya.
- Palm, C.A., Myers, R.J.K. & Nandwa, S.M. (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. In *Replenishing Soil Fertility in Africa. SSSA Special Publication No. 51* (R.J. Buresh, P.A. Sanchez & F. Calhoun, eds.), pp. 193–217. SSSA; Madison, U.S.A.
- Remonde, R., Villamora, L. & Simonides, E.J. (1992). Labour demand for organic farming. *ILEA Newsletter*, **8**, 4.
- Saleem, M.M.A. (1998). Nutrient balance patterns in African livestock systems. *Agriculture, Ecosystems and Environment*, **71**, 241–254.
- Sanchez, P.A., Shepherd, K.D., Soule, M.J., Place, F.M., Buresh, R.J., Izac, N.A-M. Mokwunyu, A.U., Kwesiga, F.R., Ndeeritu, C.G. & Woome, P.L. (1997). Soil fertility replenishment in Africa: An investment in natural resource capital. In *Replenishing Soil Fertility in Africa. SSSA Special Publication 51* (R.J. Buresh, P.A. Sanchez & F. Calhoun, eds.), pp. 1–46. SSSA, Madison, U.S.A.

- Scialabba, N. (2000). Factors influencing organic agriculture policies with a focus on developing countries. In *Proceedings of the 13th International, IFOAM Scientific Conference* (T. Alföldi, W. Lockeretz & U. Niggli, eds.), p. 624. IFOAM; Tholey-Theley, Germany.
- Sedogo, M.P., Lompo, F., Bado, B. & Hien, V. (1989). Techniques for collecting and recycling crop residues, and the effects of transformation products on soil and crops. In *Agricultural Alternatives and Nutritional Self-Sufficiency for a Sustainable Agricultural System that Respects Man and his Environment. Proceedings of the IFOAM 7th International Scientific Conference* (A. Djigima, E. Nikiema, D. Lairon, & P. Ott, eds.), pp. 282–294. IFOAM; Tholey-Theley, Germany.
- Shouwenburg, J. Ch. van & Walinga, I. (1967). The rapid determination of phosphorus in presence of arsenic, silicon and germanium. *Analytica Chimica Acta*, **37**, 271–274.
- Sturmheit, P. (1985). *A Comparison between Mineral Fertilizer and Composting Systems*. Family Farms; Magoye, Zambia.
- Tanaka, A. (1974). Cited in Müller-Sämann, K.M. & Kotschi, J. (1994), above.
- Tiffen, M., Mortimore, M. & Gichuki, F. (1994). *More People Less Erosion. Environmental Recovery in Kenya*. ACTS; Nairobi, Kenya and ODI; London, U.K.
- Werf, E. van der & De Jager, A. (1993). Agronomic and economic potential of sustainable agriculture in South India. *American Journal of Alternative Agriculture*, **8**, 185–191.
- Werf, E. van der., Kariuki, J. & Onduru, D.D. (1997). Methodological issues in comparative agro-economic on-farm research assessments of organic versus conventional farming techniques. *Biological Agriculture & Horticulture*, **14**, 53–69.
- Woomer, P.L. & Muchena, F.N. (1993). Overcoming soils constraints in crop production in Tropical Africa. In *Sustaining Soil Productivity in Intensive African Agriculture* (Y. Ahenkorah, E. Owusu-Bennoah & G.N.N. Dowuona, eds.), pp. 45–56. Technical Centre for Agricultural and Rural Cooperation, ACP-EU; Wageningen, The Netherlands.

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