Organic Resource Management in Kenya

Perspectives and Guidelines

Edited by

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Forum for Organic Resource Management and Agricultural Technologies

FORMAT, Nairobi

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Published by Forum for Organic Resource Management and Agricultural Technologies (FORMAT), P.O. Box 79, The Village Market 00621, Nairobi, Kenya. Email: formatkenya@yahoo.com

☞ Visit the FORMAT internet site at *www.formatkenya.org*

This publication was made possible through grants from the Rockefeller Foundation to the Sustainable Agriculture Centre for Research, Extension and Development in Africa (SACRED Africa) and the Tropical Soil Biology and Fertility Programme of UNESCO's Nairobi Office

Front cover photographs: Traditional green vegetable cooking in a clay pot (upper left) and burning fuel briquettes prepared from paper and dried leaves (lower right). Cover and chapter logo designs by Adeline Sirengo.

Citation: Savala, C.E.N., Omare, M.N. and Woomer, P.L. (Eds.). 2003. Organic Resource Management in Kenya: Perspectives and Guidelines. Forum for Organic Resource Management and Agricultural Technologies, Nairobi, Kenya. 184 pp.

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Table of Contents

Table of Contents (continued)

Introduction

Forward Organic Resource Management

The Forum for Organic Resource Management and Agricultural Technologies serves as a platform for promoting innovation among those seeking to make better use of what is too often overlooked. These under-utilized organic resources include crop residues, agro-industrial by-products, domestic wastes and native plants with poorly understood properties. Perspectives on the value of organic resources differ greatly. For example, on large farms, crop residues are considered a disposal problem while the poorest of smallhold farmers must scavenge for crop roots as a source of cooking fuel.

The rush towards modernized agriculture has bypassed better use of what was already available in rural areas, and the traditional knowledge to realize this lost advantage is held by fewer members of the rural community as time passes. Meanwhile in urban areas, accumulating garbage subjects residents to offensive sights and odours as well as unnecessary health risks. Waste recycling is too often viewed by planners and much of the public as a large-scale industrial process, not as an opportunity for cottage industry or more efficiently operated households.

But we humans are very adept at responding to changing circumstances, usually because we are responsible in one way or another for the changes in the first place. If necessity is the mother of invention, then under-utilized organic materials must be the father because without curious minds and busy hands it is unlikely that we will improve our wellbeing and surroundings. Ambitious humans do not allow useful materials to be wasted and through a process of trial and error, we will develop means to turn adversity into advantage, and as we develop experience and skills, we discover the solutions that hopefully will not lead to greater, unforeseen problems in the future.

As Lamech Nyangena concluded in his hand-drawn poster at the first FORMAT event in September 2000, "*Surely nothing is useless!*" While some sophisticates dismissed this proclamation by a smallhold tea farmer from Kisii district as simplistic, most in attendance rallied to the call and, over the next two annual FORMAT events, many things had surely become valuable! Water hyacinth was being processed into compost, animal feed and handicrafts. Pest control products prepared from the neem tree were carefully documented and attractively packaged, rather than resembling "backroom concoctions". Useful oils, exudates and gums were being recovered and marketed by entrepreneurs, and their new products were provided free publicity by national news organizations. Seeds and products from under-recognized traditional crops were displayed and distributed. Research officers and farmers stood shoulder to shoulder examining composts prepared from different materials and stored in different ways. Cooking briquettes, household items, even plastic fence posts fabricated from domestic wastes were displayed and being marketed by entrepreneurial self-help groups.

FORMAT events include friendly contests in pumpkin growing, composting, briquette-making and other organic resource management skills.

The grassroots had tapped into opportunities that could not have been imagined only two years earlier!

Each of the three annual FORMAT events held in Nairobi was only able to accommodate about 160 participants. During every concluding discussion, the organizers were correctly reminded that potential beneficial impacts were being restricted by the size and location of our events. I will not describe in detail the time and energy required by a few volunteers to secure funding and organize the annual FORMAT events, but be assured it was no easy task. Rather than simply justify their past efforts in terms of time and resources, the organizers "turned the tables" on participants' concerns, and challenged them to contribute chapters on their different interests that would be combined into a book on organic resource management in Kenya. This publication is intended to "take FORMAT" to a wider audience and to formalize the knowledge presented at FORMAT events. The enthusiastic response by FORMAT members has led to the production of this book. Keep in mind that many of FORMAT's most dedicated participants are not particularly experienced authors, and that many innovators are much attached to the fruits of their efforts and do not write with the polish and dispassionate review of journalists or scientists. Nonetheless, the final product is unique in its coverage and a valuable asset to anyone with interest in grassroots development and innovative resource management. "*Surely nothing is useless*", particularly this book!

Exhibits at the FORMAT-West event in 2002 included processing traditional vegetables, composting, biogas generation, domestic waste recycling and many other topics of interest.

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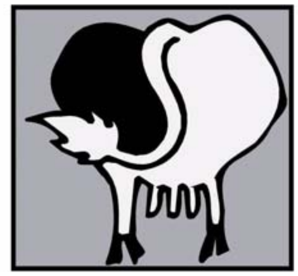
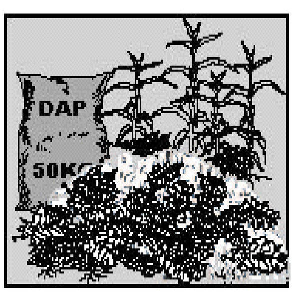
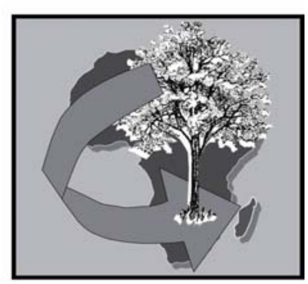


Part 1

Agricultural Resource Management





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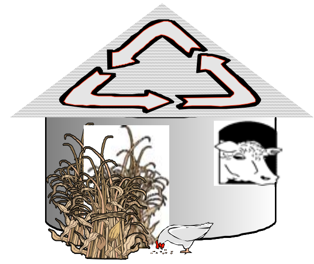

Chapter 1

Organic Resource Management in Smallhold Agriculture

John K. Lekasi

To articulate the principles of organic resource management, it is important to understand the types of materials that are referred to as organic resources. In agriculture, organic resources can simply be described as those organic materials that are used in agriculture as external or recycled inputs to produce crops either for subsistence or for commercial purposes. This type of farming is particularly characterized by the addition of low-value external inputs into the system. Technologies used to manage organic resources and crop production are directed toward soil and water conservation and soil fertility maintenance. Materials that are commonly used in these farming systems include:

- fresh, dried or composted livestock and poultry manure
- crop residues that are recycled after a crop is harvested
- green manure obtained either on or off the farm
- biomass resulting from short to long-term fallows
- agro-industrial by-products such as coffee husks or sugarcane bagasse
- forest litter, bark or wood shavings
- coarse organic materials applied as surface mulches

The management of these organic resources varies in terms of preparation prior to utilization as inputs. For instance, management is a determinant of choice of application rate, method of application and whether to use them alone or in combination with other inputs. An understanding of the kind of benefit a farmer is likely to accrue from the use of the particular organic resource of choice can help guide on the type of management to invoke at any stage of crop production (Box 1). For example, optimization of biological activity and storage conditions both contribute to the quality of compost, and greatly affects its usefulness as an organic fertilizer. On the other hand, composting results in biomass loss during decomposition. Compost is better applied to soil or used in potting mixtures, while the original resource would better serve as surface mulch.

Organic Resource Utilization in Agriculture

The beneficial role of organic resources in crop production has been recognized for a long time. The capacity of organic resources to provide nutrients, especially nitrogen (N), phosphorus (P) and potassium (K) is one such benefit. Other benefits include an increase in cation exchange capacity (CEC), improved water holding capacity and infiltration rate, and decreased bulk density. This section describes the different roles organic resources play in crop production with special emphasis on composts and manure.

Nutrient release by organic resources

A widely recognized role of organic resources in agriculture is the supply of nutrients. When organic resources are applied as soil amendments, they decompose with a fraction stabilized as soil organic matter (SOM). There are several factors that affect efficient mineralization and subsequent utilization of nutrients by a growing plant. Availability of nutrients is a balance between two opposing processes namely, nutrient mineralization and nutrient immobilization. When organic amendments are applied to the soil, micro-organisms and soil fauna decompose the materials to release nutrients. At the onset of decomposition, the microorganisms require nutrients from the soil in order to metabolize organic materials. In the process, the microorganisms compete with the plants for the same nutrients: the process of nutrient immobilization. A high energy substrate that is low in nutrients will result in net immobilization as it decomposes. Others that are rich in nutrients will result in net mineralization. When the microbial population

Box 1. Manure Preparation

The chemical composition of cattle manure is influenced by the diet of the animal and the manner the manure is collected, stored and handled before utilization (Kirchmann, 1985; Mugwira and Murwira, 1997). In order to maintain the consistency of manure quality, it is important that proper knowledge is acquired of manure collection, storage and utilization that would minimize nutrient loss and allow the nutrients to be readily available to the plants.

We gain insight into the factors regulating manure “quality” by analyzing manure that has been derived from different diets, with different organic materials added and with different storage strategies. The advantages of storing manure in a pit or covered heap must be better understood. To avoid leaching from the storage heap or pit, it is advisable to cover the manure and store it in a sheltered location.

reaches a maximum and substrate becomes limiting, then nutrient mineralization increases. The net nutrient mineralization is the difference between the nutrient mineralization and nutrient immobilization when the former exceeds the latter.

Earlier in plant growth, it is advantageous if the organic materials added to the soil mineralize nutrients slowly and the rate of nutrient mineralization increases as the plant growth progresses. As the plant matures, it is expected that a good soil amendment will have released adequate nutrients for optimum plant growth. Closer synchronization of nutrient mineralization and plant nutrient demand ensures efficient utilization of organic inputs applied to the soil. Organic materials that mineralize too readily subject mineralized nutrients to losses through processes such as leaching and volatilization. On the other hand, organic materials that release nutrients later in the season will not benefit the plant or crop as it will have matured with inadequate availability of nutrients during the critical growing stages. This example is most applicable to annual crops because perennials require a steady supply of nutrients during seasons with adequate moisture availability.

Organic resources and soil moisture conservation

Availability of adequate soil moisture is a factor that is critical at determining the amount of nutrients that are mineralized and absorbed by the plant. Application of organic resources maintains moisture levels which are considered to be more favourable for plant growth. For example, even under drought conditions, fields applied with manure, have been shown to retain moisture for a longer period than fields that have not received manure.

Excessive soil moisture is not beneficial because it may cause leaching of nutrients beyond the reach of plant roots and an insufficient supply of oxygen to plant roots. Excessive soil moisture also results in anaerobic conditions that cause nutrients to occur in forms that are unavailable to most crops. Mineral soils that contain more soil organic matter tend to be better structured, resulting in improved drainage.

Soil moisture conservation can also be achieved by use of organic materials as surface mulches. Mulched organic materials later decompose and become additional sources of plant nutrients. Carbon dioxide is generated as a byproduct of decomposition. This gas provides carbon during the process of photosynthesis and crop productivity is favored by increasing its concentration within the plant canopy. Organic mulches also create favourable conditions for soil macrofauna that serve as soil engineers by their channeling and burrowing activities.

Mulches suppress weed emergence and reduce the cost of weeding (Lekasi *et al*., 1999) as well as improving soil physical conditions. The beneficial effect of mulch in soil moisture conservation and other effects with respect to crop growth are demonstrated in the example of mulching cabbage with banana residues (Table 1), a practice that improves yield and promotes soil biological activity.

Table 1. Application of banana mulch in conjunction with other management practices on cabbage yield

Practice[1]	Cabbage yield[2] (t ha^{-1})	Earthworm population (000's ha^{-1})	Macrofauna biomass (kg ha^{-1})
Unweeded fields			
no inputs	1.0	333	10
banana residue applied as mulch	3.5	1833	107
plastic mulch	14.8	1500	58
Weeded fields			
no mulch	10.3	1167	28
banana residue applied as mulch	25.2	4333	290
NPK fertilizer applied to crop	46.2	1967	153

[1]Banana residue mulch was applied at 15 t ha^{-1} while plastic mulch was to conserve moisture. [2]Cabbage yield $LSD_{0.05}$ = 19.7. There was no significant difference on cabbage yield between the inorganic fertilizer and mulch treatments.

There are different sources of organic materials that farmers can use in soil management. The choice of organic materials depends upon the availability in the farm and their alternative uses. In the case of soil and water conservation, any material that can be used as mulch is most suitable regardless of its nutrient content. Good mulch should cover the soil adequately to minimize runoff and erosion. This will allow water infiltration and at the same time reduce weed infestation. Some organic materials used as mulch may be long or short lasting depending on the age and texture at the time they are applied. Other factors, such as termite infestation, can have negative effects on the utilization of organic materials in many locations. Organic materials used primarily for soil nutrient replenishments need to be considered more critically since the availability of the nutrients is controlled by many factors. In general, the amount and ease at which nitrogen is released from the organic materials is generally used as a measure of suitability of that material as a soil amendment.

Organic Resource Management and the Environment

Organic resource management should be practiced in such a manner that the environment is not harmed. This section gives a summary of attributes that are related to environmental issues with regard to management and utilization of animal wastes, with emphasis on intensive farming systems. This type of production system often produces concentrated animal wastes. Livestock producers should particularly recognize the threat their operations pose to surface and ground water. Prevention of air and water pollution by animal wastes requires proven methods of source reduction, storage, preservation, distribution and utilization of plant nutrients in the animal wastes (Waggoner *et al.*, 1995). The main sources of environmental pollutants are nutrients originating from animal excreta (feaces and urine) and compound derivatives after undergoing composting during storage. Gaseous loss of N from animal waste through volatilization and denitrification are potential sources of environmental pollution and greenhouse gas emissions.

Leached nutrients are transported in runoff and ground seepage and later deposited in groundwater and streams. The extent to which plant nutrients in animal waste are readily leached also depends on the nature of the compounds carrying the nutrients before they dissolve in the transportation medium. A study reported by Pakrou and Dillon (1995) has shown urinary-N leaching to 15 cm of up to 40% for irrigated pasture and up to 24% for non-irrigated pastures within one day of application. The remainder of the remaining urinary-N was converted from urea to ammonium within the same day. The fate of such ammonium depends on the soil conditions and is greatly susceptible to leaching losses if soil moisture is high, or to gaseous loss as ammonia if the soil pH is basic (>7.0).

These studies have demonstrated that livestock systems have the potential to contaminate the environment if animal wastes are not handled in a manner that would minimize N volatilization and denitrification and also reduce leaching of other nutrients. On a global scale, agriculture emits large amounts of greenhouse gases and leaches nutrients into surface and ground waters. Care must be exercised to restrict these negative environmental impacts when organic resources are being processed for use as plant nutrients. For example, water hyacinth (*Eichhornia crassipes*) invasion of Lake Victoria has been attributed to leaching of nutrients from the surrounding urban and rural areas into the lake, thereby encouraging proliferation of this water weed to uncontrollable levels (Woomer *et al.,* 1998), yet techniques are available to process water hyacinth into useful products.

The Roles of Organic Resources

The roles of organic resources in improved and sustained crop production are physical, chemical and biological in nature.

Physical functions. Organic matter (OM) binds soil particles into aggregates, giving rise to good soil structure and associated soil porosity, important in relation to root proliferation, gas exchange and water retention and movement. Crop residues or tree prunings left on the surface of the soil will reduce soil loss through erosion and subsequent humification of these materials. Beneficial effects of surface OM include reductions in soil temperatures, splash, crusting and compaction as well as soil moisture storage.

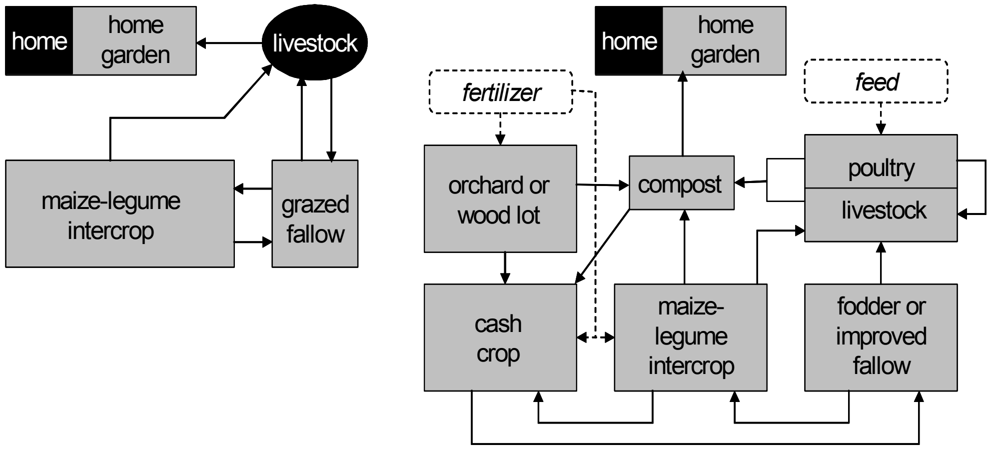

Figure 1. Major organic resource flows within subsistence, cereal-based farming (left) and mixed enterprise, market-oriented agriculture (right). Note that a greater assortment and more uses of organic resources emerge as farm operations diversify and that greater reliance may be placed upon crop rotation and purchased inputs (fertilizer and feed).

Chemical functions. Continuous organic inputs to soils enhance plant nutritional status, particularly in relation to direct supply of nitrogen (N), phosphorus (P), sulphur (S) and potassium (K). There is evidence that organic N and S are readily mineralized to inorganic forms more readily than the organic P. Incorporation of organic N and S protects these elements from leaching. The slow release of N, S and P through mineralization is synchronized with plant requirements, to a certain extent, offering the prospect of developing management practices for improving soil fertility and nutrient supply through timed application and resulting decomposition patterns. Organic inputs enhance cation exchange capacity (CEC) particularly in sandy soils. Organic inputs reduce aluminum (Al) toxicity and P-fixation in strongly acid soils with oxide mineralogy.

Biological functions. SOM stimulates the activities of macrofauna and microorganisms in soil which in turn contribute to nutrient release. Earthworms influence physical and biological conditions of the soil, which interact to effect nutrient supply to plants. Litter and SOM are the main food for earthworms. Organic inputs stimulate soil microbial biomass which may in turn immobilize nutrients, either temporarily or longer depending on the nutrient concentration of the inputs. The decomposition process is catalyzed by the soil microorganisms and fauna (termites, mites and collembola), and the microflora (bacteria, fungi), which together, constitute the soil biomass. In the tropics, SOM decomposes rapidly due to higher temperatures and favourable moisture conditions but decomposition is slower in drier or cooler environments.

Conclusion

A profound transition is underway in East Africa as smallhold farmers move from subsistence, cereal-based farming to mixed-enterprise, market-oriented systems (Figure 1). In subsistence systems, relatively few resources are available and their use is straightforward, with crop residues from maize-legume intercrops fed to relatively few livestock and the obtainable manure applied to home gardens. This trend leads to nutrient depletion in crop outfields, particularly when land is no longer available for natural fallow. As their systems diversify, a wider range of organic resources become available to land managers and more possible uses emerge. Those resources that serve as feed for confined animals are generally used for that purpose. Livestock manure is more fully recovered, and generally composted and applied to cash crops, but is also available to fodder and field crops. Income generated through cash cropping allows for purchased inputs, particularly feed and fertilizer. Low fertility patches or fields are corrected through the use of specialized technologies including strategically combined fertilizers and short-tem improved fallows. Field and fodder crops are more frequently rotated. Composting makes better use of assorted organic resources, and allows for improved nutrient contents of otherwise lower quality materials. Orchard and other tree enterprises are initiated that not only generate revenue, but also biomass that is used elsewhere on the farm. Household enterprises may also extend beyond agriculture, particularly into cottage industries. This sort of diversified organic resource management leads to better lives and contributes to rural transformation.

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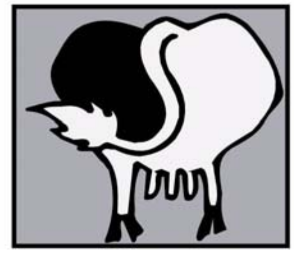

Chapter 2

Livestock Management and Manure Quality

John K. Lekasi and Stephen K. Kimani

There is great concern over soil fertility decline in arable lands of the East African Highlands. In Kenya, it is estimated that 64% of the population resides in the highlands, with maximum population densities of over 1000 people km^{-2}. Losses of nitrogen (N) and phosphorus (P) were estimated at 42 and 3 kg ha^{-1} yr^{-1} respectively in the period 1982 to 1984. This decline is, in part, related to increased cropping intensity on shrinking smallholder farms, as many households subsist on less than 1 ha, and to the limited use of inorganic fertilizer. A system to check this problem of soil fertility decline has been developed where the small farms are utilized in a way that provides inputs in an intensive and integrated manner.

Integration of livestock and crop cultivation in a complementary manner is described as a mixed or crop-livestock management system. One important advantage of integrated farming is the opportunity to convert by-products and waste from one activity into inputs for another. This form of horizontal integration has environmental as well as economic benefits. The livestock provides inputs such as manure and draft power for crop production with crop by-products being used as animal feed.

Many mixed farming systems in Sub-Saharan Africa rely upon organic matter recycling to maintain soil productivity. Yet continuous land cultivation has resulted in nutrient depletion, decline in soil organic matter and loss of physical structure thereby leading to reduced crop production (Murwira *et al.*, 1995). The cycling of biomass through animals into manure and urine that fertilize the soil is an important linkage between livestock and soil productivity in these systems. A move from extensive livestock management based on grazing to intensive stall feeding of livestock requires more feed of high quality from improved harvesting and storage techniques (de Leeuw, 1997). The effort that is put into these intensive systems may be wasted if the manure obtained from such systems is not adequately managed. A survey was conducted among smallholders in Kariti administrative location in Central Kenya. Emphasis was placed on establishing the popularity of various types of stall bedding as well as their influence on manure quality. A link between manure quality in terms of nutrient composition and physical composition, colour, smell and biological activity was investigated.

Table 1. Chemical characteristics of manures collected during the survey of 299 farms in Kariti, Central Kenya.

	C:N ratio	Carbon (%)		N	P	K	Ca	Mg
		Organic	Soluble	------------------(%)-----------------				
Minimum	5.3	6.5	0.12	0.33	0.06	0.43	0.00	0.05
Maximum	81.3	49.7	8.0	1.91	0.75	7	1.34	1.19
Mean	23.1	24.5	1.97	1.12	0.31	2.39	0.26	0.51
SD[1]	9.6	8.8	1.30	0.33	0.12	1.07	0.21	0.19

[1]SD = Standard Deviation

Cattle Management

Table 1 presents chemical characteristics useful in determining manure quality based upon a survey of 299 farms in Central Kenya. Note that considerable differences were observed between the highest and the lowest values of the quality parameters of these manures. These variations may be associated with the way the manures are handled, processed and stored. While nutrient concentrations serve as indicators of manure quality, these measurements do not reflect the actual amount of nutrient that could be available within the farms because manures with lower nutrient concentration might be available in larger supply.

Animal Management Factors Affecting Manure Quality

A summary of animal management factors affecting manure quality is presented in Table 2. Animal housing and floor type influenced the P and Ca concentration significantly while drainage had an effect on the C/N ratio and N concentration. Bedding significantly influenced the C/N ratio and P concentration while roofing type affected all the quality parameters under consideration except the C/N ratio, N and Ca concentrations. Including feed concentrates within diets also affected the P concentration of resulting manures. From these results, we conclude that zero grazing units with concrete floors without bedding that contain livestock whose feeding regime includes food supplements will produce better manure than other systems. Furthermore, following recovery, manure that is periodically turned will better conserve its nitrogen.

Effect of Feed Concentrates on Manure Quality

A trial was conducted to establish the effect of feeding cattle a high protein feed supplement on the quality of the manure. There were significant differences between the feacal and urine nitrogen contents of the excreta in response to the different rates of concentrates fed to the animals. Animals fed on high levels of concentrates produce excreta with larger amounts of N. The relationship between

Table 2. A summary of significant factors that affected manure quality parameters

Factors	Number of farms	Mean
Housing effects on P content		
Zero grazing	20	0.42% P
Improved boma	240	0.30% P
Traditional boma	19	0.24% P
Floor type effects on P content		
Soil	286	0.30% P
Concrete	12	0.41% P
Feed concentrates effects on P content		
+ Concentrate	193	0.31% P
- Concentrate	86	0.28% P
Bedding mineral effects on N content		
+ Bedding	114	420 mg kg^{-1}
- Bedding	27	804 mg kg^{-1}
Bedding effects on carbon-nitrogen ratio		
+ Bedding	198	23.9
- Bedding	83	21.1
Turning effects on mineral N content		
+ Turning	61	667 mg kg^{-1}
- Turning	80	362 mg kg^{-1}

the daily N intake per kilogram mean live weight of the steers and the N excreted in feaces and urine are shown in Figure 1. The N intake ranged between 0.300 and 0.458 g kg^{-1} LW_{mean} day^{-1} while N excreted ranged between 0.075 and 0.209 g kg^{-1} LW_{mean} day^{-1} and between 0.033 and 0.055 g kg^{-1} LW_{mean} day^{-1} in feaces and urine, respectively. The total N excreted (urinary + feacal N) ranged between 36 and 58% of the total N intake. Between 21 and 31% of total N excreted was contained in urine while the rest was excreted in the feaces. A linear relationship was observed between the daily N intake (NI) and the daily N excreted in feaces and urine with the urine better correlated to N intake than the feacal N. Similar relationships have been reported by Kirchgessner and Kreuzer (1986) who also observed that as the crude protein increased in the diets so did the feacal N excreted.

The difference in urinary N output may be explained by N intake, ranging between 60-180 g day^{-1}. This means that the diet offered was just sufficient to provide energy and protein needs leaving only modest amounts excreted in urine. Indeed, Mason (1969) observed that high fibre diets such as clover-rye grass hay and oat straw resulted in significantly higher undigested dietary N in feaces than concentrate supplemented diets in sheep. High fibre diets encourage enhanced rumen microbial activities culminating in richer feacal N excretion contain more bacterial byproducts.

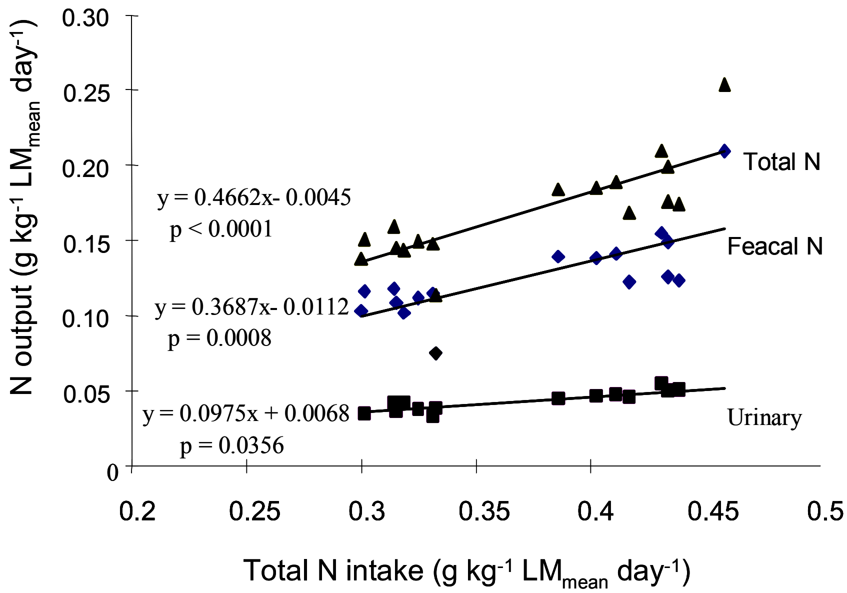

Figure 1. The relationship between nitrogen intake and N output (excreta) of steers raised in the Central Kenyan Highlands

Crop Residue Management

Crop residues are utilized for various purposes depending on the types available and the diversification of the farming system. When left lying in the field following crop harvest, straw, trash and stover enhance soil and water conservation and slowly recycle nutrients. Since most tropical soils are highly weathered, smallhold farmers in Kenya depend upon organic matter to recycle nutrients and sustain productivity (Sanchez, 1976; Murwira *et al.*, 1995). Crop residues are well suited for this purpose. In an intensive crop-livestock farming system, crop residues are frequently used as livestock feed while the manure and urine produced are used to produce crops and fodder (Tanner *et al.*, 1995). The release of nutrients from manure applied to soil is more rapid than from crop residues, and exhibits a pattern that coincides more closely with crop nutrient demand. This nutrient release is highly dependent on the composition and microbial degradability of the farmyard manure (Dewes and Hűnsche, 1998).

Conclusion

The type of animal housing, storage strategies and the type of feed provided to farm animals each affect manure quality (Figure 2). For composted materials, the initial components that are combined determine the nutrient content and physical characteristics of the resulting product. It is expected that if one begins with higher quality materials, then the final compost will also be of higher quality if the appropriate composting, handling and storage procedures are followed.

Figure 2. This basic "zero-grazing" unit holding dairy cattle includes a roof, water storage tank and feeding trough. A mixture of manure, urine and bedding is regularly recovered and used as organic inputs to soil.

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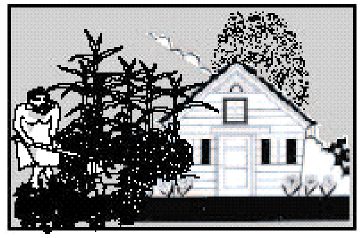

Chapter 3

Organic Resource Management in Smallholds of Central Kenya

Lucy W. Gichinga and Jane M. Maluvu

Smallhold farmers derive their organic resources largely from within their farms. The most crucial factor is how farmers identify those resources and decide on appropriate approaches to effectively utilize them. The farming system produces different by-products from various farm enterprises. These by-products are important resources and when well processed and strategically applied result in much more efficient nutrient cycling and livestock-crop interactions (Lekasi *et al*., 2001). Farmers must mobilize human labour and knowledge required to collect, transport, process, store and apply the resources on the farm. Activities such as composting are labour intensive, and subject to other factors such as bad weather, lack of space and financial resources. Small scale farmers also face competing demands for food and income which lead them to engaging in farming enterprises that best meet these needs.

In this chapter, we present a case study of how Lucy Wanjiku Gichinga, a smallhold farmer in Central Province of Kenya, manages organic resources generated within her farm (Figure 1) and how interactions with other interests in the agricultural and rural development communities have influenced her farming strategies. Lucy practices mixed enterprise agriculture involving dairy, poultry

Figure 1. A well-mulched vegetable garden at Gichinga farm. The mulch is incorporated into the soil after weeding. The vegetables are also planted with chicken manure in a garden surrounded by grevillea trees

Table 1. Sources and application of organic resources within a smallhold farm in Central Kenya.

Enterprise	Resource and use
Poultry rearing	chicken feed waste for sale, livestock feed and manure/bedding
Dairy	manure, urine and bedding waste for fertilizer, composting and fuel briquettes
Food crops	residues for animal feed, mulch, compost and sale
Livestock fodder	residues for compost, mulch
Vegetables	residues for mulch, animal feed, sale and compost
Agroforestry trees	fodder, fuel wood, mulch, soil erosion control and fertility management

and crop production, agroforestry, small-scale milk processing and marketing. The farmer has established dairy and poultry units, grows green vegetables, fodder, maize, bananas and trees on 1.5 ha. The farmer's strategy is to raise poultry and dairy animals that generate useful organic wastes and farm income. She integrates crop production and agroforestry into the system in order to utilize wastes arising from the livestock and poultry enterprises as organic inputs, but also utilizes residues from the crop and tree production as animal feed, mulch and compost. Chicken feed waste is used to feed the cattle, while cow dung is used to make fuel briquettes for heating the poultry (Table 1). Vegetables, milk, eggs and broilers are sold to raise income to cater for family needs and sustain farm production.

Application of Organic Resources

Chicken waste. Poultry droppings and feed waste are valuable resources on the farm. After every six weeks, the broilers are slaughtered, their feed waste, droppings and bedding are collected from the chicken houses and stored in water-tight bags in a cool-dry place. The waste is later screened to separate feed waste from droppings and saw dust. The screened feed waste is added to animal fodder as concentrate and fed to dairy animals. Supplementation of animal feed with chicken feed waste results in significant increase in milk production (Lekasi *et al*., 2001).

Box 1. Value of poultry waste
From an average of 300 chicks raised over six weeks, the farmer generates 1120 kg of feed waste, 1000 kg of chicken droppings and 600 kg of saw dust. The farmer sells poultry feed waste for use as livestock feed at KSh. 5 per kg to neighbouring farmers. This generates a farm income of about KSh. 5600 after every six weeks. This sale assists the farmer to recover 30% of the cost of chicken feed purchased for KSh. 17 per kg.

Dairy animals fed with chicken feed waste produce feaces and urine with higher concentrations of plant nutrients, especially nitrogen and phosphorus. When this manure is mixed with other wastes during composting, they greatly improve the quality of manure compost, resulting in improved crop yields. The separated chicken droppings and sawdust may be used in composting or applied directly to the field. Chicken droppings are used mostly to grow green vegetables in the farm (Figure 1).

Livestock waste. The zero grazing units at the farm are constructed in such a way that allows for easy separation and collection of cow dung, urine and feed waste. Animal manure is applied differently depending on the needs at the time of disposal. First it is mixed with other farm wastes to make compost (Figure 2). Just before the rains, it is applied directly to the field prior to ploughing. At times, fresh cow dung is mixed with water and applied as liquid fertilizer in the field. Lack of labour sometimes forces the farmer to allow animal urine and fresh cow dung to flow directly from the dairy units to the crop fields. Although less efficient, this method still provides nutrients to crops. As an alternative to managing loss of manure and other crop residues, the farmer has prepared a compost pile that is supplied with adequate water, frequently turned and covered by shade from grevillia trees. The compost pile is located adjacent to the animal

Figure 2. Piling of animal and feed waste, crop residues and household wastes for composting. Composting is performed in close proximity to the animal sheds.

pens (Figure 2) for ease of transportation of crop residues, feed waste and cow dung to the pile and compost.

Agroforestry, Crop and Fodder Production

Integration of trees into the farming system ensures supply of fodder, fuel wood for cooking and heating of the chicken units, and litter that is used as mulch or mixed with other farm wastes to prepare compost (Figure 3). Also, as agroforestry leaves drop litter, it is added to the soil to improve the soil organic matter resulting in improved crop and fodder production (Figure 3; Rocheleau *et al*., 1998). The main tree species grown include *Grevillea robusta* (Figure 3), *Sesbania sesban, Calliandra calothyrsus*, pawpaw, avocado and guava. These trees are grown in hedgerows and live fences. The trees are also harvested for human and animal food, wood fuel and fencing. The farmer maintains a home garden surrounded by these trees where kale, spinach, pea and bean are grown for sale. Other crops grown in the farm include maize and bananas. Besides the produce, the crops generate residues that are used as animal feed, mulch and also for compost production.

Excess compost and chicken manure is occasionally sold to neighboring farmers who have smaller land sizes that cannot support sufficient composting and livestock operations. Due to planned and frequent use of compost and manure, production of napier grass (*Penesetum purpureum*) as the main livestock feed has been sustained. During dry seasons, the farmer sells surplus napier grass to other farmers at KSh 15 for an area of grass covering 1m^2. Planting of napier grass is preceded with application of compost, referred to as the *Tumbukiza* planting method. By this method, an average of two wheelbarrows of compost (≈100 kg) is applied per 1 m^2 "hole" in order to supply the plants with nutrients and maintain soil moisture. Surface applied compost is later incorporated into the soil during weeding to enhance nutrient supply to the napier grass.

Figure 3. Intercropping of trees in the farm with napier grass to realize the benefits of agroforestry.

Production of bananas is a more

recent enterprise. The farmer planted tissue cultured varieties provided by the Kenya Agricultural Research Institute (KARI). This variety has a short maturing period and high yields. The bananas are planted with compost, which is also often applied to the growing plants. The bananas are intercropped with kale, maize, beans, napier grass and grevillea trees. All the intercrops perform particularly well due to the small stature of the banana variety and the pruning regime which maintains 3 or 4 pseudostems per banana. Banana leaves and prunings are also used for mulch, animal feed and compost. The farmer sells dry banana fibres to artisans for use in weaving handicrafts. Banana production has become an essential farming activity because of its high price and its ability to supply the household with food and organic inputs.

Other Resource Management Activities

In order to sustain chicken production and improve waste management in the farm, fuel briquette making was initiated at the farm (Figure 4). The briquettes are made from charcoal waste (dust), fresh cow dung, soil, dry plant leaves and grass. These ingredients are collected and mixed in proportions of 3:2:1:1 and water is added to make kneading easier. The paste is cut out into cylindrical fuel briquettes and dried in the sun for three weeks. When ready, the briquettes are stored in a dry place and used along with charcoal to provide heating in the poultry units and for cooking. Six briquettes ignited with some charcoal heats the chicken house for up to 12 hours. The same quantity of charcoal alone would burn for less than one hour. Assuming 1 kg of charcoal will burn for one hour, then for twelve hours the farmer needs up to 12 kg of charcoal, and the jiko has to be refilled every hour. Assuming a cost of KSh 15 per kg of charcoal, the farmer will spend KSh 144 per day to heat the chicken units. Given the relative minimal cost of preparation of briquettes, the service provided by six briquettes saves a substantial amount of cash that the farmer would otherwise spend on heating the poultry units.

Figure 4. Fuel briquette making supports poultry production saving the farmer the use of electricity and extra charcoal costs

Composting is another major waste and residue management activity that is undertaken at the farm. Animal waste, feed waste, household waste, crop residues, tree litter, weeds and grass are regularly collected and piled in a compost heap. Fresh materials are added at various intervals as mature compost is separated and applied to the filed. Compost is applied at planting and to the field prior to weeding. The farmer intends to experiment with vermicomposting, and hopes to shorten the composting period by use of the commercially available "activators".

Sustaining Farm Production

Crop, dairy and fodder production is sustained in the farm through learning and applying various organic resource management strategies (Figure 5). During the dry seasons, crops and napier grass are irrigated and mulched. Irrigation water is provided by borehole and performed thrice weekly. Application of sufficient compost at planting, supplemented by manure additions before weeding, greatly improves water holding capacity of the soil while supporting faster and better growth of crops. The sale of fresh milk and processed milk products, vegetables, napier grass, eggs and chicken meat ensures a constant flow of income to the farm to cover daily farm and household costs. Their main dairy products include yoghurt, sour milk and cream. The farmer belongs to a women group that operates a small dairy shop in Nairobi as a means of obtaining better prices for their milk.

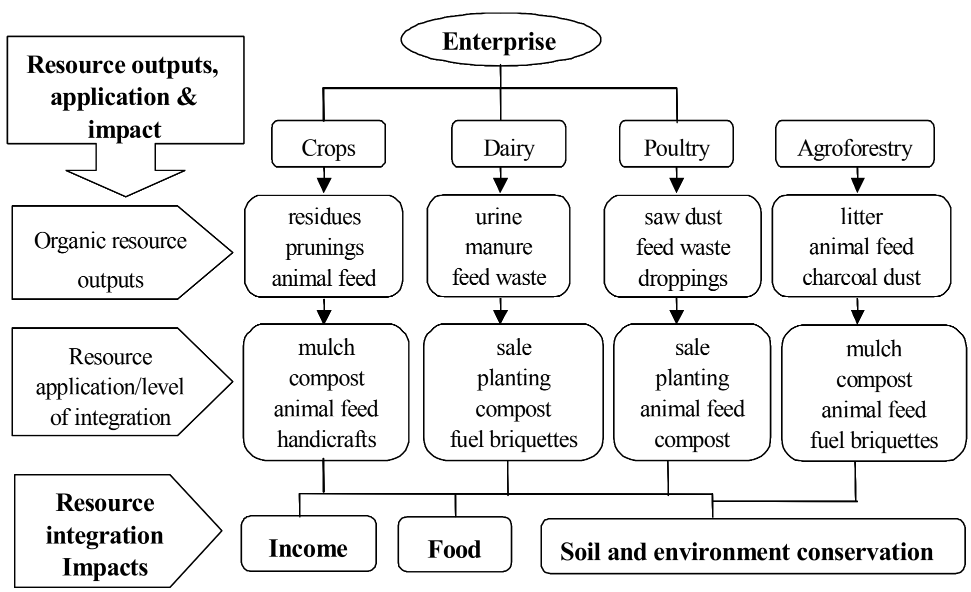

Figure 5. An integrated organic resource management system practiced in the farm

Figure 6. Lucy Gichinga standing aside her exhibit during a past national FORMAT event

Membership in a farmers association and a savings society has helped the farmer to participate in training and agricultural events, which have formed a major source of knowledge and skills applied in the farm. The farmer has attended training activities organized by Kenya Agricultural Research Institute, Ministry of Agriculture, Zero Grazing Society of Kenya, Kenya Institute of Organic Farming, local churches and community-based organizations, and events organized by the Forum for Organic Resource Management and Agricultural Technologies (FORMAT) (Figure 6). The farmer also benefits greatly from farmer-to-farmer visits. Skills learned from these interactions include dairy farming, milk processing, packaging and marketing, vegetable production, fodder production and management, composting and manure management, soil fertility management and agricultural waste management. The farmer accesses credit from Pride Africa and Cooperative Bank of Kenya for the purchase of inputs for the dairy, crop and chicken enterprises. The rates of interest for the loans from Pride Africa are considerably lower than those charged by commercial banks. The organization does not require any securities for the loans as long as the farmer is regular in repaying the loan. In 2001, the farmers' association was registered as a self-help group in Kiambu district and has been working with various research and development organizations to promote agricultural production in the area. For three consecutive years, the farmer has won awards for "innovation and community service through organic resource management" during the national events organized by FORMAT between 2000 and 2002 (Omare *et al*., 2003).

Figure 7. An example of "tight" nutrient cycling occurs in Central Kenya when manure is applied to napier grass.

Conclusion

Farming for business is a concept that smallhold farmers must better pursue in order to achieve their expectations of higher living standards. Diversifying and integrating farming enterprises and targeting production for the market are the most dependable ways of survival in smallhold farming. Efficient and innovative utilization of available organic resources can greatly improve and sustain production in a smallhold farming system (Figure 7). Farmers need to be better trained and provided information on the various management approaches. Organizations both belonging to the public and private sectors must work more closely with small-scale farmers, and to learn from them as clearly many farmers have discovered important solutions to problems experienced elsewhere. Marketing produce is a major constraint to many small-scale farmers because they are not well organized and positioned to compete with established enterprises. Access to credit has to be improved to enable farmers diversify into various income generating farming enterprises. But these constraints can be overcome as evidenced by the profitable innovations practiced at Gichinga farm and elsewhere!

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Chapter 4

Organic Resources for Soil Fertility Management in Eastern Kenya

Monicah Mucheru, Daniel Mugendi, Ruth Kangai, James Kung'u, Jayne Mugwe and Alfred Micheni

Soil erosion, decline in soil fertility and insufficient fodder production are some of the major problems facing agricultural production in Kenyan smallholder farms today. These problems are more pronounced in the densely populated highlands of central Kenya with over 700 persons km^{-2} (Government of Kenya, 2001). The soils in this area are Humic Nitisols with moderate to high inherent fertility (Jaetzold and Schemindt, 1983). However, with an annual net nutrient depletion exceeding 30 kg N (Smaling, 1993) as a result of soil erosion and continuous cropping, soil fertility has markedly declined over time. The use of inorganic fertilizers is generally low, less than 20 kg N ha^{-1} (Murithi *et al.,* 1994) which does not meet the optimal crop nutritional requirement. Maize yields achieved by smallscale farmers in the region are less than 1.5 t grain ha^{-1} compared to the potential of 6 to 12 t ha^{-1} (Wokabi, 1994).

Surveys conducted in the area indicate that farmers are fully aware of the declining soil fertility (as expressed by declining crop yields), but in most cases do not have readily available resources to replenish the soil fertility (Murithi *et al*., 1994). Research results reported by Gachengo (1996), Gitari *et al.* (1997), Mugendi *et al.* (1999) and Mutuo *et al.* (2000) describe a positive effect due to the use of biomass from mucuna, crotalaria, manure, tithonia, calliandra and leucaena for soil fertility improvement in the Kenyan highlands. These organic inputs and tree hedges are important components in soil fertility replenishment and need to be evaluated by farmers. A participatory trial was therefore established in maize growing areas of Meru South District in 2000 with the main objective of examining and extending nutrient replenishment and conservation technologies intended for the small-scale farmers.

Study Area and Field Approach

The study was conducted in Meru South District, which is characterized by complex farming systems dominated by perennial cash crops, food crops and livestock (Micheni *et al.,* 1999). The area is in the main coffee/dairy/maize Land Use Systems (LUS) with an altitude of approximately 1500 m above sea level, annual mean temperature of 20^0 C with an annual rainfall varying from 1200 to 1400 mm (Jaetzold and Schemindt, 1983). The rainfall is bimodal, falling in two seasons, the long rains (LR) lasting from March through June and short rains (SR) from October through December. The average farm size is about 1.5 ha per household.

An off-station soil fertility trial was established in March 2000 on a farm with degraded soils and arranged as a randomised complete block design (RCBD) with three replicates. The trial was researcher-designed and researcher-managed, and the test crop was maize (*Zea mays* L, var. H513). Thirteen external soil fertility amendment inputs were applied to give an equivalent amount of 60 kg N ha^{-1} except for the herbaceous legume treatments where the N quantity was determined by the amount of biomass harvested and incorporated in the respective treatments. The fourteenth treatment received no nutrient inputs. One row of the herbaceous legumes was planted between the maize rows, two weeks after sowing. The legumes remained in the field after maize was harvested until land preparation the next season. Then, they were harvested, weighed, chopped and incorporated into the soil.

Farmers' field days were held during each season at the grain filling stage. Farmers toured the experimental plots and treatment effects were discussed in an informal setting. They were then requested to select the treatments they wished to test on their farms. During the 2001/2002 short rains, farmers established many of the technologies in their own farms. The trials established in the farmers' fields were of two types: researcher-designed but farmer-managed, and farmer-designed and farmer-managed. The farmers applied the organic inputs as explained during the field days though some of them adapted the technologies to fit their more specialized conditions. Data collected from both off-station and on-farm trials were statistically analysed using spreadsheet and statistical computer programs.

Maize Grain Yield

The off-station average maize grain yields in the different treatments across the four seasons are presented in Table 1. Tithonia with half the recommended rate of inorganic fertilizer recorded the highest maize grain yield of 4.8 t ha^{-1} followed closely by sole tithonia (4.7 t ha^{-1}). The absolute control treatment recorded the lowest maize grain yields across the treatments and seasons with 1.5 t ha^{-1} followed closely by the sole crotalaria with 1.7 t ha^{-1}.

The integration of organic and inorganic nutrient sources of N gave higher maize grain yields as compared to the sole application of organic materials during the four seasons of the study. Integration of inorganic and organic nutrient inputs can be considered as a better option in increasing fertilizer use efficiency and providing a more balanced supply of nutrients (Palm *et al.,* 1997; Vanlauwe *et al.,* 2002).

Table 1. Off-station maize yields under different technologies during the various rainy seasons at Chuka, Meru South District

Candidate management	Seasons: 2000 LR	2000/2001 SR	2001 LR	2001/2002 SR	Mean
	Grain weight (t ha^{-1})				
Control	0.6	2.6	1.2	1.5	1.5
Crotalaria	0.9	2.1	1.9	1.8	1.7
Mucuna	1.3	4.0	2.4	3.7	2.6
Crotalaria + 30 kg N ha^{-1}	1.4	3.4	2.4	3.2	2.6
Mucuna + 30 kg N ha^{-1}	1.4	4.4	3.2	2.7	2.9
Calliandra	0.7	6.0	2.8	4.5	3.5
Manure + 30 kg N ha^{-1}	1.2	6.5	4.9	2.9	3.9
Leucaena + 30 kg N ha^{-1}	1.3	6.1	3.7	4.4	3.9
60 kg N ha^{-1}	1.4	6.3	5.0	3.2	4.0
Cattle manure	1.2	6.7	3.7	4.6	4.1
Calliandra + 30 kg N ha^{-1}	1.1	5.8	4.3	5.1	4.1
Leucaena	1.0	6.1	4.0	5.8	4.2
Tithonia	1.2	6.6	4.3	6.5	4.7
Tithonia + 30 kg N ha^{-1}	1.3	6.8	5.4	5.6	4.8
SED	0.2	0.4	0.7	0.7	0.5

The lower maize grain yield in the 2000 and 2001 LR season may be attributed to the low precipitation, averaging only 126 mm in the 2000 LR season. During the 2001 LR season, 431 mm of rainfall was recorded but 86% of the rains fell within the first two weeks. This insufficient and unevenly distributed rainfall reduced the availability of nutrients to the maize plants. Fortunately, the 2000/2001 and 2001/2002 SR seasons were characterized by higher precipitation (average 698 and 806 mm, respectively) that was well distributed throughout the season.

Technology Adoption

Five well-attended farmers' field days were held at the grain filling stage during each season. Many farmers (24%) were willing to try the sole tithonia management probably because of its local availability and because they did not need to be educated on how to handle it. To overcome the problem of limited availability (as 30 t of fresh biomass is required to provide 60 kg N ha^{-1}), farmers said they would plant tithonia hedges, and most of them knew how to propagate it through cuttings. Calliandra was also highly rated because of its supplementary role as an animal feed. The farmers with animals said that they would use calliandra as an animal feed to improve the quality of their manure; however the ones with no animals wished to use it as a direct source of soil fertility.

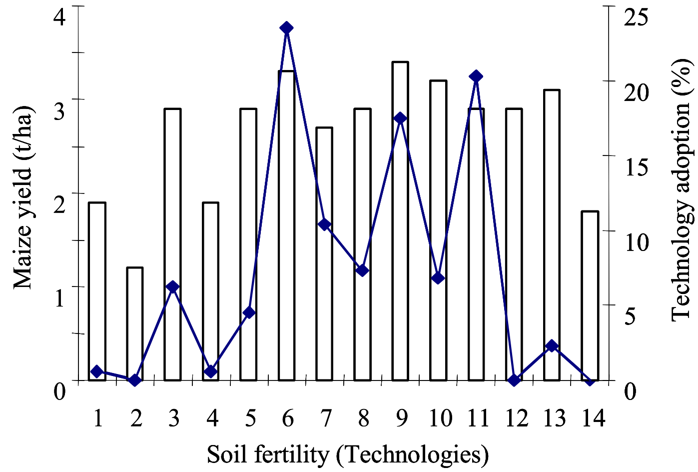

Figure 1. Average maize grain yield across the seasons and the % adoption of the technologies at the beginning of the 2001/2002 SR season in Chuka, central Kenya. Technologies (1= mucuna; 2 = crotalaria; 3 = mucuna + ½ fert; 4 = crotalaria + ½ fert; 5 = manure; 6 = manure + ½ fert; 7 = tithonia; 8 = calliandra; 9 = leucaena; 10 = tithonia + ½ fert; 11 = calliandra + ½ fert; 12 = leucaena + ½ fert; 13 = rec fert; 14 = control).

Results showed that many farmers (52%) were interested in adopting technologies that combined both the organics and inorganic inputs while 46% were interested in sole organic inputs, and 2% in mineral fertilizers. The higher percentage with the integration could have been as a result of better maize performance and because some of the farmers could afford the half rate of the recommended inorganic fertilizer and were therefore willing to supplement the organics. However, most of the farmers who were willing to adopt the sole organics were not in a position to purchase inorganic fertilizer. No farmers were interested in adopting leucaena and 30 kg N ha^{-1} together or sole crotalaria despite the fact that these were not the poorest performing technologies (Figure 1). This could have been associated with other factors other than the maize grain yield. Sole calliandra and crotalaria with half recommended rate of inorganic fertilizer had the lowest yields in the 2000 and 2001 LR seasons but despite this, 10% and less than 1% farmers were willing to test them respectively.

On-farm Maize Yields

Farmers participating in the field days selected some of the technologies that were demonstrated to them and started testing them in their farms during the following 2001/2002 short rains (Table 2). The results indicate that their crop yields improved as a result of using the introduced technologies, however the yields varied among farms. This could be as result of the inherent variability within each farm and the differences in day-to-day management. For instance, applied cattle manures varied in quality depending on the feedstuff, storage and decomposition duration. Tithonia did not perform exceptionally well on-farm as it had done in the

Table 2. Average on-farm maize yields (t ha^{-1}) under different technologies during the 2001/2002 SR, 2002 LR and 2002/2003 SR seasons at Chuka, Meru South District

Candidate management	2001/2002 SR	2002 LR	2002/2003 SR
	-----------------Cropping Seasons-----------------		
	---------------Grain weight (t ha^{-1})-----------------		
Control	1.0	0.4	1.4
Tithonia	1.9	1.3	2.4
Leucaena + 30 kg N ha^{-1}	2.4	2.1	--
Crotalaria	--	0.4	2.5
Mucuna	--	1.6	2.7
Manure + mucuna + 30 kg N ha^{-1}	--	4.3	3.3
Tithonia + 30 kg N ha^{-1}	--	2.8	3.4
60 kg N ha^{-1}	3.2	3.0	3.9
Manure + tithonia	1.8	--	4.2
Cattle manure	0.3	2.1	4.2
Calliandra + 30 kg N ha^{-1}	--	1.2	4.4
Crotalaria + 30 kg N ha^{-1}		3.3	4.5
Leucaena	3.7	0.2	4.7
Cattle manure + 30 kg N ha^{-1}	2.8	3.0	4.8
Mucuna + 30 kg N ha^{-1}	2.4	1.2	5.3
SED	1.1	1.2	1.5

Figure 2. A farmer participating in the trials explains a new technology to others during a visit to his farm.

off-station trial. This could be due to the lower amount of tithonia applied by farmers

The participating farmers observed better performance of crops using the organic resources and that the cost of production had been reduced and soil fertility improved. Soil erosion had also been reduced where the tree hedges were established. Milk production had also improved after feeding cattle with calliandra. Farmers also observed that soil pests were reduced with the organic resource use additions especially where tithonia was applied. In the 2002 LR season, 84% of the farmers who had started to work with these technologies continued with them and there were 25 additional new farmers examining the technologies during this season. In the 2002/2003 SR season, another 43 new farmers started working with these technologies. A total of 206 farmers evaluated these technologies during the 2002/2003 SR season.

Farmers who were already practicing the new technologies initially mentioned lack of sufficient biomass (tithonia, calliandra and leucaena) and finances to purchase manure and fertilizer in the required quantities. Over time, many farmers have established hedgerows along fences and on terraces. For example, by the 2001/2002 SR season 25, 40 and 45 farmers had started planting tithonia, calliandra and leucaena, respectively. They also learned how to manage manure

Figure 3. Farmers visiting a field trial in Chuka in Eastern Kenya.

more effectively, leading to lower nutrient losses. Some of the farmers have modified the technologies to better suit their own conditions in very innovative ways. For example, though the test crop was maize, some farmers started growing vegetables using tithonia. Other farmers' modifications include the different inputs, for example, tithonia + manure or tithonia + manure + fertilizers. Currently, a bag of tithonia is retailed at KSh 50, unlike two years earlier when it did not have an economic value within the community.

Conclusion

Prunings of tithonia added to the soil, and tithonia prunings combined with half the recommended rate of inorganic fertilizer resulted in impressive yields over four cropping seasons and many farmers have adopted these new practices. Attempts to expose farmers to improved, locally-available technologies through field days has resulted in positive impacts within the project area, particularly where farmers are acutely aware of their farming constraints and are willing to test and adopt new solutions to their problems. Indeed, farmers are trying some of the technologies in their own farms and indication of improved crop yields in these farms has been observed, although the magnitude of yield improvement varies between locations. The largest challenge that is facing farmers in adoption of these cut-and-carry technologies is the labour required pruning the hedges and transferring the prunings to their fields.

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Organic Resource Management in Kenya:
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Edited by C.E.N. Savala, M.N. Omare
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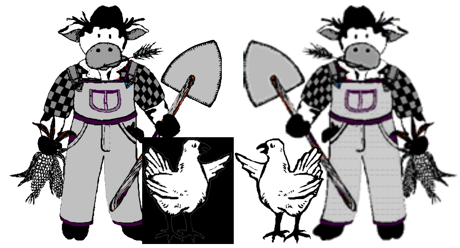

Chapter 5

Organic Resources for Integrated Nutrient Management in Western Kenya

J. Robert Okalebo and Paul L. Woomer

Researchers provide various definitions and explanations for Integrated Nutrient Management (INM). Some researchers argue that it is a practice whereby both organic and inorganic nutrient resources are applied simultaneously to increase crop yields. Other scientists argue that in addition to organic and inorganic inputs, other agronomic practices of planting good seed, early planting, weed, pest and disease control, should be the components in the definition of INM. A third school of thought stresses that nutrient cycling is the centre of INM. In a review by Franzluebbers *et al*. (1998), INM attempts to "combine the old and new methods of nutrient management into ecologically sound and economically viable farming systems that utilize available organic and inorganic sources of nutrients in a judicious and efficient way". By this definition, INM optimizes all aspects of nutrient cycling.

From the biological aspect of soil fertility management, INM seeks tight nutrient cycling with synchrony between nutrient demand of crops and nutrient release within the soil while minimizing loss of nutrients through leaching, runoff, volatilization and immobilization (Figure 1). Janssen (1993) noted that sustainable soil management must involve the judicious application of both mineral and organic nutrient resources within ecologically sound production systems, such as crop rotation, mixed cropping and agroforestry.

In western Kenya, however, mixed cropping, with minimal nutrient inputs is the norm and crop rotation is secondary to continuous maize cropping. Too few farmers recognize the benefit of improved soil fertility through nutrient recycling. Leguminous intercrops and short fallows contribute nitrogen to the soils through biological nitrogen fixation, but this process and root nodulation is not widely recognized as beneficial by farmers. On the other hand, mineral fertilizers and livestock manure are considered important inputs, but are usually available in too short supply. The advantages and disadvantages associated with the use of both organic and inorganic nutrient resources are summarized in Table 1.

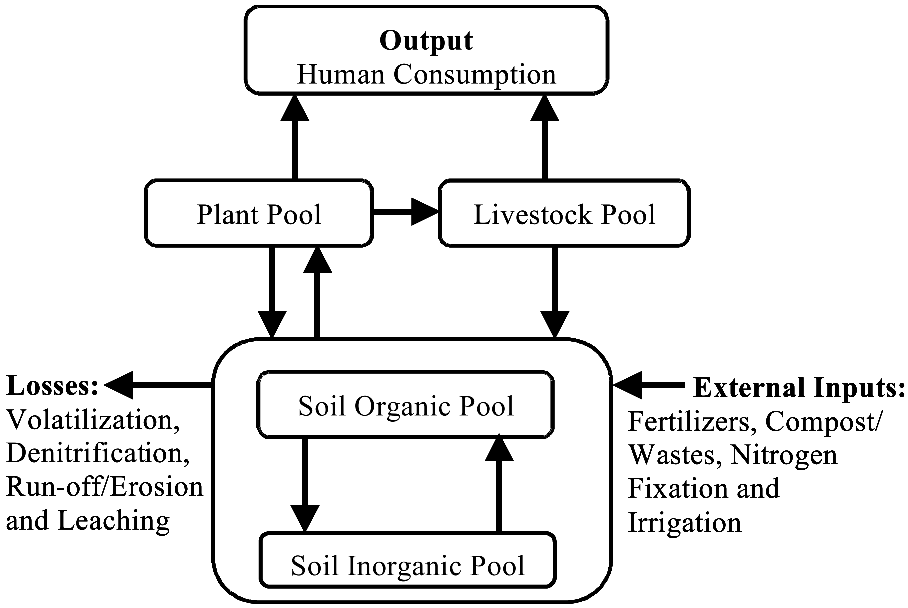

Figure 1. Pools and fluxes of nutrient cycling in agroecosystems (after Franzluebbes *et al*., 1998).

Types and Qualities of Organic Inputs

Because of their incomplete understanding by farmers, organic inputs and their informed management offer a wide range of opportunities within smallhold farming systems. In farms where manure or inorganic fertilizers are not applied, weeds, crop residues and roots remaining in fields contribute recycled nutrients through decomposition. Crops acquire nutrients from deeper soil horizons and soil parent materials as well. Therefore, the size of crop yields and the duration when acceptable crop harvests are obtained in absence of nutrient inputs are dependent upon the inherent fertility of soil, including the past management of the farm, local climatic conditions, especially the amounts and patterns of rainfall distribution within seasons, and the nutrient requirements of the crop. Other factors include the abundance, frequency and types of nitrogen-fixing organisms and the loss of nutrients due to removal, incorporation and grazing of crop residues. The high nutrient demand by maize removes large quantities of nitrogen (N), potassium (K) and phosphorus (P) from soils while nitrogen-fixing legumes may result in a net nitrogen gain in soils. Organic inputs available at the farm level are often inadequate to supply all nutrient needs (Probert *et al.,* 1992). This is reflected by the regular importation of farmyard manure from pastoral lands in Kajiado to Kiambu district in Kenya (Lekasi *et al*., 2001) by farmers growing higher value crops for Nairobi and export markets, despite the abundance of nearby local smallhold dairy enterprises.

Table 1. A comparison between inorganic fertilizers and organic inputs (after Woomer *et al.,* 1999)

	Nutrient source	
Feature	Mineral fertilizer	Organic resource
Nutrient concentration	Higher and based upon labeled nutrient contents	Lower, unknown and variable between "batches"
Nutrient availability	Rapid chemical dissolution, subject to loss through leaching and sorption	Slower release, regulated and protected by soil biological process
Acquisition and cost	Costly, purchased in imperfect markets with few credit opportunities	Locally produced or gathered, often in short supply and with competing uses
Labour requirements	Easily applied and compatible with other field operations	Higher recovery and handling efforts, may interfere with other field operations
Environmental impacts	Negative at excess rates, pollution of aquatic systems	Positive, favour carbon sequestration and soil biodiversity

The quality of organic nutrient resources has a significant role on the effectiveness of the materials on crop yields. Organic input quality refers to the nutrient content and the concentration of lignin and polyphenol, two secondary compounds that regulate decomposition and bind with its products. Large variations in quality occur among sources of manure, including between nearby farms (Table 2).

Before the nutrients in organic inputs can benefit a crop, the materials must undergo decomposition and nutrient mineralization. Inputs that are higher in nutrients and lower in lignin and polyphenol, especially those with C:N ratios less than 10, will rapidly decompose and release nutrients into soils. Green manure decomposes more readily than crop residues and woody tissues (Waigwa and Okalebo, 1998; Figure 2). Variations in decomposition and nutrient release patterns may have either positive or negative effects. In fields of fast-growing annual crops such as maize, there is need for rapid nutrient release to adequately provide nutrients at the early stages of growth, whereas with perennials, a more steady nutrient release is required to provide nutrients over time.

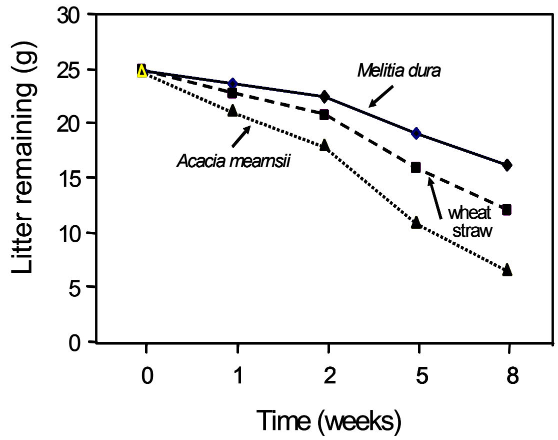

Figure 2. Decomposition of three different litters with contrasting qualities over time

A wide range of organic nutrient sources is available to farmers but different types of organic inputs must be handled and applied in different ways for them to achieve their maximum effect. The guidelines in Figure 3 integrate both the physical and chemical characteristics of organic inputs that influence their decomposition and nutrient release patterns. For example, the guidelines indicate that when the N content of the organic material is >2.5%, as in leguminous green manure, one is advised to apply this material directly at a recommended rate without additional N input from inorganic fertilizer. Unfortunately, higher quality organic resources are too often in short supply, requiring that farmers apply low quality materials (e.g. N <2.5%, C:N ratio >25) such as crop residues (Table 3). Reduction in crop yield from these materials after their incorporation into the soil is not uncommon, particularly when added in large quantities (Okalebo *et al*., 1997).

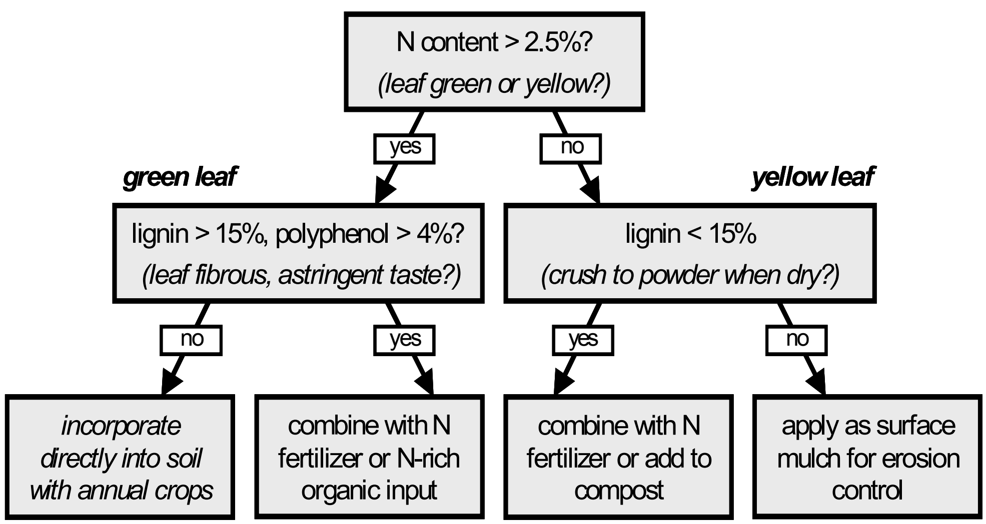

Figure 3. A decision tree to guide the allocation of organic resources used as inputs to soil (after Giller *et al*., 2000; Palm *et al*., 2001).

Table 2. The nutrient content of different cattle manures from some farms in Kenya (after Probert *et al*., 1992).

Source of manure	Ash	C	N	P	K	Ca
	-------	-------	-------	%	-------	-------
Nzioko farm	94	4.4	0.63	0.14	0.84	1.24
Mbaki farm	92	5.1	0.55	0.16	1.10	1.94
Ngao farm	94	1.6	0.17	0.08	0.26	0.58
Ngului farm	88	3.4	0.33	0.13	0.66	0.96
Makuti farm	89	4.4	0.50	0.14	0.68	0.84
Kioko farm	91	3.0	0.35	0.20	0.78	1.47
Fresh cattle manure	81	-	1.28	0.45	2.65	1.26
Old cattle manure	74	-	0.49	0.31	1.65	0.85

Table 3. Effects of crop residue and nitrogen fertilizer additions on the grain yield of maize grown on a Ferralsol near Eldoret, Kenya.

Treatment	Grain yield (kg ha^{-1})
Control (no inputs)	2833
80N	4883
WS + 0N	2051
WS + 80N	4785
SYT + 0N	2832
SYT + 80N	5567
$LSD_{0.05}$	1030

WS = wheat straw, SYT = soybean trash applied at 2 t/ha; N = nitrogen applied as urea at 80 kg N/ha; WS contained 0.67% N, 0.09% P, 8.63% lignin and 1.11% polyphenolics; SYT contained 1.07% N, 0.20% P, 9.31% lignin and 1.17% polyphenolics.

The negative effect of low quality organics is explained in terms of nutrient immobilization because the microorganisms active in organic matter decomposition (e.g. bacteria, fungi) also obtain their nutrient requirements from the decomposing organic materials. Microbes in effect have “priority access” to applied resources because of their size, abundance, distribution and metabolism.

Case Studies on the Use of Organic Inputs

Large amounts of maize stover and wheat straw are produced in the high agricultural potential areas of Uasin Gishu and Trans Nzoia districts in Kenya (Lwayo *et al*., 2000). In the sugarcane growing areas, similar quality residues are also available in large quantities. Disposal of these materials may in some cases even pose problems to land managers. These materials are often left in the field,

Figure 4. Field testing PREP-PAC in Western Kenya; maize production in untreated soil (a) and one year after nutrient replenishment with PREP-PAC (b).

fed to cattle or used as cooking fuel. Frequently, residues remain in the field to dry and then burned to facilitate tillage operations. Burning recycles some nutrients, but loses most carbon, nitrogen and sulfur to the atmosphere. Yet alternative, more environmentally-friendly methods of utilization are available.

The large scale farmers with suitable machinery may chop the materials soon after harvests and incorporate them into the seedbed. This system facilitates the decomposition and nutrient release from materials including the improvement of soil physical characteristics, such as soil structure and infiltration. Decomposition and residual effects are enhanced by incorporating a small amount of mineral N with the residues and then plough the mixtures into the seedbed, preferably before the successive crop is planted. With regard to incorporation of N into residues, a study in Uasin Gishu district investigated maize response to the addition of wheat straw and soybean trash. These two residues have contrasting qualities and are also common within the district. Treatments where mineral N was incorporated with these residues significantly out-performed those without N incorporation (Table 3). Conservation tillage strategies retain chopped crop residues as surface mulch, and then direct seed into them, a management approach that relies upon specialized equipment and chemical control of weeds later in the growing season.

PREP-PAC is a product intended to correct the symptomatic low fertility patches common in croplands of western Kenya. It is based upon the principles of integrated nutrient management (Figure 4). Low soil fertility patches result from nutrient removal and their formation is enhanced by continuous cropping of land

Table 4. Maize grain yield at 3 sites in western Kenya (after Obura *et al*., 2001)

Treatment	Grain Yield (kg ha^{-1})		
Location	Siaya	Bungoma	Kabras
Control	1578	1619	1595
Biofix	2228	1247	2257
Urea	1930	1183	2616
MPR	2510	2435	4174
Urea + Biofix	2281	1083	2889
MPR + Biofix	3930	2406	2949
MPR + Urea	3741	3028	2298
MPR+ Urea + Biofix	4814	2711	3151
$LSD_{0.05}$	1529	988	1348

without the addition of external nutrient sources (Woomer *et al*., 1997). A diagnostic survey in Vihiga, Busia and Bungoma districts showed that low soil fertility patches occupy between 10% and 30% of farm land and that the soil test parameters (pH, C, N and available P) were lower in these patches compared to the similar parameters obtained in soils within close areas where crops grew vigorously (Nekesa *et al*., 1999). PREP-PAC consists of 2 kg Minjingu phosphate rock, 200 g of urea, 120 g of food legume seed, rhizobial inoculant, gum arabic sticker and lime pelleting material. Instructions are provided in English, Kiswahili and local languages. The product costs KSh 41 (US $0.55) to assemble.

PREP-PAC was tested on smallhold maize-legume intercrops in several low fertility soils of western Kenya. Treatments were selected to determine the response of maize and N-fixing soybean intercrops to individual PREP-PAC components and their interactions (Table 4). The yields varied with the treatments and sites, and ranged from 1.1 to 4.8 t ha^{-1}. Although the main PREP-PAC components (PR, urea and Biofix) applied individually or separately increased maize yields, the PR sole application gave the highest yield increases across the 3 sites, particularly in Kakamega with red soil of high clay content. On the average, PR combinations with Biofix and urea resulted in significant maize yield increases, but the complete pack (PR + urea + Biofix) gave the highest yield increase of 205% above control in Siaya. These yields resulted in 2.6 and 3.7 benefit to cost ratios in Bungoma and Siaya, respectively, good returns by any standard. Fuller discussion on soybean yields is given in Obura *et al*. (2001).

The practice of planting improved relay fallows with maize is promoted by the World Agroforestry Centre and other research organizations in western Kenya. The fallows continue to grow for several months following crop harvests and then the leaves and twigs are incorporated into the soil and stems are recovered for use as poles and cooking fuel. Poor establishment of these fallows occurs on the least fertile soils, a situation that may be corrected through the strategic application of mineral fertilizers.

On-farm studies were performed in western Kenya to determine the agronomic and economic viability of intercropping improved fallows of *Crotalaria grahamiana* and *Tephrosia vogelii* with maize and beans in the same season. These studies indicated that the application of 30 kg N and 20 kg P ha^{-1} as urea and Minjingu phosphate rock, respectively, greatly enhances the growth of both maize or beans due to greater biomass accumulation and incorporation of the improved fallow. Incorporating the fallow with MPR increased the levels of nitrate in soils, resulting in better yields of maize over several consecutive cropping seasons (Ndungu, 2002). Fallow biomass incorporated into soils at 2 t ha^{-1} in conjunction with 20 kg P ha^{-1} as Minjingu phosphate rock was an economically viable option for improved fallow technology, assuming that land availability does not restricting its adoption by farmers.

Conclusion

This chapter discussed the concept of Integrated Nutrient Management and the important role of organic resources within that strategy. Several examples were provided where organic materials by themselves were unable to guarantee crop performance and sustain soil fertility but, the combination of organic and mineral inputs has resulted in greatly improved crop yields under smallhold farming conditions in western Kenya. This improvement is due, in part, to manipulating soil biological processes in favor of better supply and timing of nutrient availability. While the utilization of nutrient-rich organic materials is direct and straightforward, fuller use of low quality organic inputs, such as maize stover or straw, requires combination with other inputs in a manner that requires understanding by land managers.

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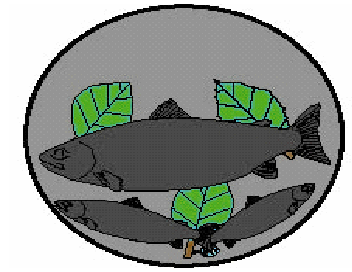
Chapter 6



Utilization of Organic Resources in Fish Farming

David Liti and Jonathan Munguti

Aquaculture involves the cultivation of aquatic organisms under partial or fully controlled conditions. Aquaculture in Kenya dates back to the colonial time (Vernon and Someren, 1960) but has faced a number of constraints that hindered its development. Among the major constraints are limited varieties of the cultured fish species and unavailability of inexpensive, locally-available diets.

At the Sagana Aquaculture Research Station in Central Kenya, efforts are underway to intensify the culture of Nile Tilapia (*Oreochromis niloticus)* and African Catfish *(Clarias gariepinus)*. Several experiments have been conducted and others are in progress to evaluate different fish feeds, both as single ingredients and in combination. Liti and Mugo (2002) evaluated the performance of single ingredients of rice bran, wheat bran and maize bran in combination with diammonium phosphate (DAP) and urea. Results from the study demonstrated that both wheat and maize bran produce similar fish yields but are more productive than rice bran. The study also revealed that fermentation of the bran does not enhance fish yields. A cost-benefit analysis showed that wheat bran is the most effective bran to use, followed by maize bran while rice bran offers the poorest returns. It is therefore recommended that rice bran should only be used when other superior feeds are not available.

Organic Resource Utilization in Fish Farming

Aquaculture production techniques can be categorized based on management intensity. Extensive culture technique occurs where natural productivity meets all the nutrient requirements of fish. Semi-intensive culture occurs when ponds are fertilized with either organic or inorganic fertilizers to stimulate natural production or when supplemental feeds are used to increase fish yields. Intensive culture occurs when all the nutritional requirements are met externally through formulated diets. The semi-intensive system is most widespread in Africa as feed requires over 50% of the operating costs of more intensive production systems (Pillay, 1992). Our work has focused upon the use of under-utilized organic materials and agricultural by-products as replacement feeds in fish production. Formulated fish diets are expensive and not readily available to small-scale farmers, in contrast to commercial livestock feeds. As a result, in most developing countries, agricultural by-products used as organic inputs to ponds and single ingredient diets offer opportunity to improve fish farming, and these materials may be effectively combined to compliment their various nutritional properties.

A number of organic materials are commonly used in Kenya as aquacultural fertilizers including chicken manure and bedding, duck droppings and cow, sheep, goat and pig dung. Others include green manure such as cut fodder and tree prunings. Organic fertilizers may also be applied to fishponds to stimulate natural food production as these inputs increase autotrophic and heterotrophic food webs. The soluble fraction supplies nitrogen and phosphorus that supports primary production by phytoplankton. The particulate component provides food and substrates for microorganisms (e.g. bacteria, protozoa) as well as acting as direct food for the fish. Most of the nutrient release occurs within a few days after addition of manure to the pond, primarily through leaching and breakdown of soluble organic matter (Nath and Lannan, 1992). Some of the advantages and disadvantages of using organic and mineral fertilizers as inputs to fish ponds are presented in Table 1. The carbon dioxide released after decomposition provides the inorganic carbon needed for photosynthesis or slowly enters the carbonic acid-bicarbonate - carbonate system that acts as a pH buffer. This buffer is important in

Table 1. Advantages and disadvantages of organic manures over mineral fertilizers in fish farming

Organic Residue	Mineral Fertilizer
Advantages	
Provides carbon in addition to phosphorus and nitrogen	Does not supply carbon
Supports both autotrophic and heterotrophic food webs	Supports only autotrophic metabolic pathways
They are less expensive	They are more expensive
They increase the buffering capacity of a pond (alkalinity increases with time)	They decrease the buffer capacity of a pond (decrease alkalinity with time)
Often in close proximity to ponds, less transportation costs involved	Usually imported, with higher associated transportation costs
Reduces pond seepage	Does not reduce pond seepage
Disadvantages	
Requires processing before application	No processing before application
Has higher biological oxygen demand	Has less biological oxygen demand
Stains pond water reducing transparency	No colour imparted to water
Bulky and difficult to handle	Not as bulky and easier to handle

protecting fish and other aquatic organisms from the adverse effects of pH fluctuations. Parts of the organic material settle as pond sediments that significantly contribute towards seepage reduction.

Fish yields are determined by several factors that include the quantity and quality of diets. The primary goal in fish farming is to transform dietary protein into fish protein (Jauncey, 1982). Protein sources in fish diets are mainly of two types, animal protein and plant protein. Inclusion of animal protein into fish diets significantly increases production costs. As proteins are generally too expensive for use in fish feed, except as feed supplements, the focus of attention becomes maximizing the efficiency of low cost plant proteins and farm wastes.

The most utilized agricultural by-products used as fish feeds in Kenya include maize, wheat and rice bran, and cotton, soybean, and sunflower seed cakes. They are normally used to supplement natural food (plankton and detritus) in the ponds. The quality of particular bran depends on the locality and the methods of processing. For example, rice bran from Mwea rice factory has a crude protein content of approximately 10% (Veverica *et al.,* 1998), however, after the collapse of the factory, individual processors emerged, and the rice bran obtained from these processors contained between 3-6% crude protein (Liti and Mugo, 2002). It was later observed that the individual processors often mixed their bran with ground rice hulls which reduced the protein content. Wheat bran is of more reliable quality with a crude protein content of 14-17%. This reliability results from the larger-scale processing of wheat. The nutrient concentrations of several feeds are presented in Table 2.

Most fish farming in Kenya relies heavily on natural food in the pond system with some supplementation of artificial feeds to increase fish yields. The feed supplements are mostly agricultural by-products that do not provide complete fish nutrition. Most of these supplements are readily available and are not utilized as human food. Farmers throughout the country have access to different feedstuffs, depending on locality. For example, a fish farmer in Kitale has better access to maize bran which is also less expensive and of more reliable quality compared to

Table 2. Proximate composition of some selected single ingredients in Kenya

Ingredients	Nutrient Concentration					
	dry matter	protein	lipid	NFE[1]	crude fibre	ash
	%					
Brewers yeast	93.0	25.0	15.4	32.0	21.9	4.7
Shrimp meal	91.0	55-60.0	6.0	5.0	4.0	23.1
Cotton seed Cake	93.0	35.9	6.7	44.5	7.1	5.8
Sunflower Cake	94.0	21-25.0	5.5	29.2	39.6	5.0
Wheat bran	-	14-18.0	6.5	59.5	16.0	4.0
Maize bran	93.0	10-15.0	4.4	70.8	11.6	3.2

[1]NFE- nitrogen free extracts

wheat or rice bran, which are relatively scarce in the area. Fish farmers near the Mwea irrigation scheme, and Ahero near Kisumu have better access to rice bran while farmers in Uasin Gishu have seasonal accessibility to wheat bran. Nonetheless, each of these materials is bagged and marketed throughout the country for use as livestock feed.

Single ingredients are often deficient in one or more of the nutrients required for growth. To overcome the deficiency, ingredients are mixed together to form a compounded feed. Formulated feeds are usually more expensive than single ingredients and therefore are formulated for species that fetch higher market prices, such as rainbow trout (*Oncorhynchus mykiss*). Compounded feeds for Nile tilapia (*O. niloticus*) and African catfish (*C. gariepinus*) are scarce and relatively expensive in Kenya, however, diets formulated for pigs and young broilers are suitable alternatives.

Several compound feeds were tested at Sagana and different commercial diets were similar in promoting fish yields and better than rice bran. Currently, on-farm formulated feeds are being tried against single ingredients and a commercially-available livestock feed (Figure 1). Preliminary results from this study have again shown that formulated feeds are more effective in increasing fish yields than single-ingredient feeds. Since animal protein is scarce and more expensive than plant protein, another experiment was designed to evaluate whether animal protein inclusion could be reduced from 12% to 6% in the diets of Nile tilapia. Preliminary results indicate that the amount of animal protein can be reduced from 12% to 6% without loss in fish performance but cannot be replaced entirely by plant protein. Table 3 presents two possible formulations using three ingredients that yield a high protein diet for tilapia. Table 4 combines five ingredients in the formulation of a diet containing 20% crude protein that may be combined using materials commonly marketed by retailers of livestock feeds. There was no improvement when supplemental vitamins were added to the feed, suggesting adequate supply of vitamins from the natural food.

Figure 1. A formulated feed that is more effective in increasing fish yields than single-ingredient feeds.

Table 3. Two formulations for Nile tilapia feed (*Oreochromis niloticus*) using three ingredients that produce a diet with 25% crude protein from locally-available materials.

Ingredient	Inclusion	Protein	Lipid	Crude fibre
	---------------	--------------- %	---------------	---------------
Shrimp meal	5.0	3.0	0.3	0.2
Cotton seed cake	39.7	14.3	2.7	2.8
Wheat bran	55.3	7.7	3.6	21.9
Total	100.0	25.0	6.6	24.9
Alternative Formulation				
Shrimp meal	5.0	3.0	0.3	0.2
Cotton seed cake	48.3	17.3	3.2	3.4
Maize bran	46.7	4.7	2.1	5.4
Total	100.0	25.0	5.6	9.0

Table 4. Dietary formulations for Nile tilapia (*Oreochromis niloticus*) using five ingredients required to make a diet with 20% crude protein from locally available materials.

Ingredient	Inclusion	Protein	Lipid	Crude Fibre
	---------------	--------------- %	---------------	---------------
Water Shrimp	8	4.8	0.5	0.3
Cotton seed cake	8.1	2.9	0.5	0.6
Wheat bran	62.1	8.7	4.0	9.9
Sunflower cake	4.4	1.9	0.2	0.7
Maize bran	17.4	1.7	0.8	2.0
Total	100	20	6	13.6

Use of Organic Resources for Fish Farming at Sagana

The Sagana fish farm is a leading aquaculture research and development center in Kenya that is operated by the Fisheries Department. The main activities at the station include extension services, training and research in fish production. The farm is located at 0°39'S and 37° 12'E and at an altitude of 1230 m above sea level. It is situated 105 km northeast of Nairobi. The facility contains a modern hatchery, holding tanks, feeder canals, production ponds and integrated fish, livestock and poultry facilities. Integrated farming applies to systems that are aimed at improving the diversity and production of a whole farm. This type of system allows for efficient utilization of farm wastes. Such a system has been set up at Sagana to boost fish production. Integration is achieved through strategic construction and placement of a zero grazing units, poultry and duck pens and sheep rearing facilities.

Figure 2. Integrated fish production and poultry rearing at Sagana aquaculture station. The use of organic fertilizers has been of great importance in enhancing fish yields at the station.

Manure from the cattle shed is flushed into a 1.6 ha fishpond constructed a few meters adjacent to the cattle shade. The cattle unit is located at a slightly higher elevation and a controlled water flow is allowed to flush through it to wash manure into the pond, thus reducing transportation costs. The manure promotes natural food webs that improve tilapia and catfish production. Diana *et al*. (1994) demonstrated that organic fertilizers result in higher primary production and consequently larger tilapia and catfish yields, apparently due to increased production of both autotrophic and heterotrophic organisms.

The use of poultry droppings is facilitated by stocking chicken and ducks in pens constructed directly over the ponds (Figure 2). Chicken manure fertilizes the water below and is also consumed directly by fish. Discarded chicken feed becomes part of the fish diet as well. The reduced transportation cost increases profit margins, which is the main goal of most commercial farmers. We recommend the use of organic inputs in fish production and have identified those organic materials that promote heterotrophic activities which in turn promote fish yields. Although in Sagana both chicken and ducks are reared, an earlier study demonstrated that ducks are better than chicken in poultry/fish integration. Ducks raised adjacent to ponds appear to be hardier and less susceptible to diseases than chickens. In addition, they are easier to house because marshy riversides and wetlands serve as excellent quarter for duck farming.

Figure 3. Feeding the fish at designated corners of the fish ponds. Natural food provides adequate vitamins for Nile tilapia in semi-intensive culture ponds.

There is a broad range of organic materials used in fish farming at the Sagana facility, however, the choice of materials used as feed greatly affects fish yields. The allocation of organic resources in fish farming also depends upon fish species, local water conditions and the intensity of pond management. Annual fish production ranges between two to nine tons ha^{-1} yr^{-1}, depending on the quality and amount of feed.

Several studies conducted using rice bran as feed have consistently produced yields of Nile tilapia between 2.4 to 3.0 tons ha^{-1} yr^{-1}. Veverica *et al*. (1998) reported Nile tilapia yields of 4.0 ton ha^{-1} yr^{-1} in fertilized static earthen ponds while Liti *et al.* (2002) reported Nile tilapia yields of 5.0 ton ha^{-1} yr^{-1} under similar conditions.

Experiments with wheat and maize bran produce yields of 6.0 tons ha^{-1} yr^{-1}. Under similar conditions, formulated feeds provide Nile tilapia yields of 7.5 ton ha^{-1} yr^{-1}. Two diets, one containing vitamin premix and the other without, were compared. The two treatments did not show any significant differences. From these observations, it was concluded that there was no need to supplement the diets with vitamin premixes. This observation suggested that natural food provided adequate vitamins for Nile tilapia in semi-intensive culture ponds (Figure 3).

Conclusion

Development in the aquaculture industry will depend upon better utilization of organic materials, particularly as fish feed. Other uses include the addition of organic materials that provide substrate to aquatic food webs that indirectly serve as feed. One way of achieving these goals or organic resource utilization is to develop training activities in integrated aquaculture. In more integrated systems, farm wastes from other enterprises can become converted into higher-value inputs to nearby fish ponds. Similarly, effluents and sediments from fish ponds may be profitably applied to croplands.

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Organic Resource Management in Kenya:
Perspectives and Guidelines
Edited by C.E.N. Savala, M.N. Omare
& P.L. Woomer, FORMAT 2003.

Chapter 7

Estimating Carbon Stocks in Smallhold Agricultural Systems

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Atmospheric change and global warming are pressing concerns that affect the future of humanity. While a majority of greenhouse gas emissions result from burning fossil fuels and from inefficient industrial processes, about 1/3 of carbon dioxide imbalances occur from land use change, particularly deforestation and soil degradation (Noble and Scholes, 2001). Accordingly, one of the most important short-term sinks for atmospheric carbon dioxide (CO_2) is through increasing carbon stocks in the plants and soils of managed and degraded lands, including smallhold farming systems of the tropics. Land managers in East Africa seldom recognize the importance of carbon stocks on their farms (Woomer *et al.*, 1997), or that environmental interests are likely to develop large scale projects in the tropics that are designed to protect and increase carbon stocks at the landscape and national scales (Trexler, 1993). Land managers who document carbon gains on their land could become compensated through these projects.

It is unrealistic to expect individuals or communities to protect and foster that which they do not understand, and this is certainly the case for carbon stocks in smallhold farming systems. Carbon (C) exists as an inseparable component of vegetation, litter and soil organic matter, and is primarily lost as an invisible gas (CO_2), factors which complicate the understanding of carbon stocks and dynamics to non-scientists. When asked what is the likely crop yield of maize in a maturing field or meters of poles in a woodlot, a land manager can often provide an educated guess, but this is not the case for system C stocks within those same land uses. Carbon seems too intangible for approximation. Yet carbon is predictable from certain perspectives. For example, it is a near constant proportion within vegetation (45% to 49%).

Estimating Carbon Stocks: Tree Carbon

An important empirical relationship exists between the tree diameter at breast height (DBH) of trees and tree aboveground biomass. Allometric equations based upon power functions, which intercept the origin, are recommended above quadratic approaches because of their greater accuracy for assigning biomass to smaller trees. For general purposes, we recommend the equations from FAO (1997) in Dry Zones (<1500 mm yr^{-1}):

$$\textbf{Aboveground tree biomass (kg tree}^{-1}\textbf{)} = \exp^{(-1.996 + 2.32 \ln D)}$$

and in Moist Zones (1500-4000 mm yr^{-1}):

$$\textbf{Aboveground tree biomass (kg tree}^{-1}\textbf{)} = \exp^{(-2.134 + 2.53 \ln D)}$$

where Y is the aboveground tree biomass in kg, exp = 2.71828… and D is the measured DBH in cm. Other equations are available for drier (<900 mm yr^{-1}) and wet zone (>4000 mm yr^{-1}) from FAO (1997). Allometric equations may be further refined by including factors for tree height and wood density (Ketterings, 2001). Measurement of tree diameter is easily made using either a diameter tape or callipers (Figure 1) but the mathematics required to convert from diameter to biomass is probably too complex for most land managers in Africa. Tree diameter (D) is readily calculated from tree circumference (C) by division by pi (pi = 3.14159…) where C = D x pi.

A simple table was prepared that allows for the estimation of tree carbon based upon established biophysical relationships. Table 1a provides the total C (in tons) contained in aboveground woody biomass of different sized trees based upon a widely employed allometric relationship between tree diameter at breast height (DBH) and total tree biomass. Table 1b also includes C in roots (+0.35) and the turnover of leaf drop (0.15 woody

Figure 1. Measuring tree diameter with a dial caliper (left) and a diameter tape (right).

Table 1a. Estimates of total tree biomass for different tree numbers and diameters at breast height (DBH) based upon aboveground biomass (AGB) where AGB C = 0.47 x $\exp^{(-1.997 + 2.32 (\ln DBH))}$ and root biomass = 0.35 AGB.

tree	DBH (cm)																
number	5	7.5	10	12.5	15	20	25	30	35	40	45	50	60	70	80	90	100
	increased tree and soil C (tons)																
1	0.00	0.01	0.02	0.03	0.05	0.09	0.15	0.23	0.33	0.45	0.59	0.75	1.15	1.65	2.24	2.95	3.76
2	0.01	0.02	0.04	0.06	0.09	0.18	0.30	0.46	0.66	0.90	1.18	1.51	2.30	3.29	4.49	5.89	7.53
3	0.01	0.03	0.05	0.09	0.14	0.27	0.45	0.69	0.99	1.35	1.77	2.26	3.45	4.94	6.73	8.84	11.29
4	0.01	0.04	0.07	0.12	0.18	0.36	0.60	0.92	1.32	1.80	2.36	3.01	4.60	6.58	8.97	11.79	15.05
5	0.02	0.05	0.09	0.15	0.23	0.45	0.75	1.15	1.65	2.25	2.95	3.77	5.75	8.23	11.21	14.74	18.82
6	0.02	0.06	0.11	0.18	0.28	0.54	0.91	1.38	1.98	2.69	3.54	4.52	6.90	9.87	13.46	17.68	22.58
7	0.03	0.06	0.13	0.21	0.32	0.63	1.06	1.61	2.31	3.14	4.13	5.28	8.05	11.52	15.70	20.63	26.34
8	0.03	0.07	0.14	0.24	0.37	0.72	1.21	1.84	2.64	3.59	4.72	6.03	9.20	13.16	17.94	23.58	30.11
9	0.03	0.08	0.16	0.27	0.42	0.81	1.36	2.07	2.97	4.04	5.31	6.78	10.35	14.81	20.18	26.53	33.87
10	0.04	0.09	0.18	0.30	0.46	0.90	1.51	2.30	3.29	4.49	5.90	7.54	11.51	16.45	22.43	29.47	37.63
15	0.05	0.14	0.27	0.45	0.69	1.35	2.26	3.46	4.94	6.74	8.85	11.31	17.26	24.68	33.64	44.21	56.45
20	0.07	0.18	0.36	0.60	0.92	1.80	3.02	4.61	6.59	8.98	11.80	15.07	23.01	32.90	44.85	58.95	75.27
25	0.09	0.23	0.45	0.76	1.15	2.25	3.77	5.76	8.24	11.23	14.76	18.84	28.76	41.13	56.06	73.68	94.08
30	0.11	0.28	0.54	0.91	1.38	2.70	4.53	6.91	9.88	13.47	17.71	22.61	34.52	49.35	67.28	88.42	112.90
40	0.14	0.37	0.72	1.21	1.85	3.60	6.04	9.22	13.18	17.96	23.61	30.15	46.02	65.81	89.70	117.89	150.54
50	0.18	0.46	0.90	1.51	2.31	4.50	7.55	11.52	16.47	22.46	29.51	37.68	57.53	82.26	112.13	147.36	188.17
60	0.22	0.55	1.08	1.81	2.77	5.40	9.06	13.82	19.77	26.95	35.41	45.22	69.03	98.71	134.56	176.84	225.80
70	0.25	0.65	1.26	2.12	3.23	6.30	10.57	16.13	23.06	31.44	41.32	52.76	80.54	115.16	156.98	206.31	263.44
80	0.29	0.74	1.44	2.42	3.69	7.20	12.08	18.43	26.36	35.93	47.22	60.29	92.04	131.61	179.41	235.78	301.07
90	0.32	0.83	1.62	2.72	4.15	8.09	13.58	20.74	29.65	40.42	53.12	67.83	103.55	148.06	201.83	265.26	338.71
100	0.36	0.92	1.80	3.02	4.61	8.99	15.09	23.04	32.95	44.91	59.02	75.37	115.05	164.52	224.26	294.73	376.34

Table 1b. Estimates of combined tree biomass and soil carbon gains for different tree numbers and diameters at breast height (DBH) based upon aboveground biomass (AGB) assuming that AGB C = 0.47 x $\exp^{(-1.997 + 2.32 (\ln DBH)}$, root biomass = 0.35 AGB, leaf drop = 0.15 AGB, fine root turnover = 0.15 AGB and soil sequestration = 0.12 t SOC t^{-1} leaf and fine root inputs

tree	DBH (cm)																
number	5	7.5	10	12.5	15	20	25	30	35	40	45	50	60	70	80	90	100
	increased tree and soil C (tons)																
1	0.00	0.01	0.02	0.03	0.05	0.09	0.16	0.24	0.35	0.47	0.63	0.81	1.25	1.82	2.54	3.44	4.55
2	0.01	0.02	0.04	0.06	0.10	0.19	0.31	0.48	0.69	0.95	1.25	1.61	2.50	3.64	5.08	6.88	9.09
3	0.01	0.03	0.06	0.09	0.14	0.28	0.47	0.72	1.04	1.42	1.88	2.42	3.75	5.46	7.63	10.31	13.64
4	0.01	0.04	0.07	0.12	0.19	0.37	0.63	0.96	1.38	1.90	2.51	3.22	5.00	7.28	10.17	13.75	18.18
5	0.02	0.05	0.09	0.16	0.24	0.47	0.78	1.20	1.73	2.37	3.13	4.03	6.25	9.11	12.71	17.19	22.73
6	0.02	0.06	0.11	0.19	0.29	0.56	0.94	1.44	2.07	2.84	3.76	4.83	7.49	10.93	15.25	20.63	27.28
7	0.03	0.07	0.13	0.22	0.33	0.65	1.10	1.68	2.42	3.32	4.39	5.64	8.74	12.75	17.79	24.07	31.82
8	0.03	0.08	0.15	0.25	0.38	0.74	1.26	1.92	2.77	3.79	5.01	6.44	9.99	14.57	20.33	27.51	36.37
9	0.03	0.09	0.17	0.28	0.43	0.84	1.41	2.16	3.11	4.26	5.64	7.25	11.24	16.39	22.88	30.94	40.91
10	0.04	0.09	0.19	0.31	0.48	0.93	1.57	2.41	3.46	4.74	6.26	8.05	12.49	18.21	25.42	34.38	45.46
15	0.06	0.14	0.28	0.47	0.71	1.40	2.35	3.61	5.19	7.11	9.40	12.08	18.74	27.32	38.13	51.57	68.19
20	0.07	0.19	0.37	0.62	0.95	1.86	3.14	4.81	6.91	9.48	12.53	16.11	24.98	36.42	50.84	68.76	90.92
25	0.09	0.24	0.46	0.78	1.19	2.33	3.92	6.01	8.64	11.84	15.66	20.13	31.23	45.53	63.55	85.96	113.65
30	0.11	0.28	0.56	0.93	1.43	2.79	4.71	7.22	10.37	14.21	18.79	24.16	37.47	54.63	76.26	103.15	136.38
40	0.15	0.38	0.74	1.25	1.90	3.72	6.28	9.62	13.83	18.95	25.06	32.22	49.96	72.84	101.67	137.53	181.84
50	0.18	0.47	0.93	1.56	2.38	4.66	7.84	12.03	17.28	23.69	31.32	40.27	62.45	91.05	127.09	171.91	227.30
60	0.22	0.57	1.11	1.87	2.86	5.59	9.41	14.43	20.74	28.43	37.59	48.32	74.94	109.26	152.51	206.29	272.76
70	0.26	0.66	1.30	2.18	3.33	6.52	10.98	16.84	24.20	33.17	43.85	56.38	87.43	127.47	177.93	240.68	318.22
80	0.30	0.76	1.48	2.49	3.81	7.45	12.55	19.24	27.65	37.90	50.12	64.43	99.92	145.68	203.35	275.06	363.68
90	0.33	0.85	1.67	2.80	4.28	8.38	14.12	21.65	31.11	42.64	56.38	72.49	112.41	163.89	228.77	309.44	409.14
100	0.37	0.95	1.85	3.11	4.76	9.31	15.69	24.06	34.57	47.38	62.65	80.54	124.90	182.10	254.18	343.82	454.59

biomass) and fine roots (0.15 woody biomass) assuming modest (0.12) annual C sequestration in soil. Table 1 provides estimates of total C resulting from different sizes and numbers of growing trees. For example, a row of 10 trees that have grown to 30 cm diameter contain 2.42 t of carbon.

The tree biomass carbon relationship is independent of land area, so that tree numbers (rows) may be obtained from different size categories (columns) and the carbon stocks estimated for any known land area, such as different sized smallholdings. Carbon stocks may not be readily interpolated between columns because of the exponential nature of the allometric function. In other words, tree biomass C for a tree 27.5 cm in diameter does not occur midway between the 25 and 30 cm diameters but rather is skewed toward the higher diameter. Extrapolation may be made, however, by extending the values obtained within the rows. For example, the value for 35 trees from a diameter size category is equal to that of 30 trees + 5 trees of that same size category. Some practice in the field will show that Table 1 provides a useful and fairly simple tool to estimate tree carbon.

Crop Carbon

Carbon stocks may also be estimated for crops based upon their yield, harvest index and root-to-shoot ratio. Harvest index is the proportion of aboveground biomass that is removed as crop yield. For example, if a one ton crop of maize grain has a harvest index of 0.35, then the total crop aboveground biomass is 1.00/0.35 or 2.86 t, and the stover is 1.86 t (or 2.86 aboveground – 1.00 t grain). Furthermore, if one assumes that grain, shoots and roots all contain 47% C and that root biomass is 0.35 of shoot biomass, then the total crop carbon at peak biomass before harvest is 1.81 t C (2.86 x 1.35 x 0.47). This relationship may be summarized as:

Peak biomass C = crop C content x (crop yield / harvest index) x (1 + root: shoot ratio)

and when the values above are substituted in the equation,

Peak biomass C = 0.47 x (1.0 / 0.35) x 1.35 = 1.81 t C

This approach was used to develop a table of crop carbon contents for different yields and harvest indices (Table 2). For example, a 2750 kg crop (= 2.75 t) with a harvest index of 0.25 contains 7.0 t C in its grain, shoots and roots, regardless of the land area upon which it was produced. This value refers to the peak biomass carbon, and it should be time-averaged throughout the year based upon the length of the growing season. Time-averaging requires that the peak season biomass and the number of wet months (the growing season) be known, and is calculated as:

Time-averaged biomass C = (peak biomass C /2) / (12 / wet months)

Table 2. Total crop carbon (tons of grain, shoots and roots) at peak biomass before harvest for different harvest indices and crop yields assuming 47% C content in biomass and roots are 35% aboveground biomass.

crop yield (kg ha^{-1})	harvest index (%) 10	15	20	25	30	35	40
	total crop C (tons) before harvest						
500	3.2	2.1	1.6	1.3	1.1	0.9	0.8
750	4.8	3.2	2.4	1.9	1.6	1.4	1.2
1000	6.3	4.2	3.2	2.5	2.1	1.8	1.6
1250	7.9	5.3	4.0	3.2	2.6	2.3	2.0
1500	9.5	6.3	4.8	3.8	3.2	2.7	2.4
1750	11.1	7.4	5.6	4.4	3.7	3.2	2.8
2000	12.7	8.5	6.3	5.1	4.2	3.6	3.2
2250	14.3	9.5	7.1	5.7	4.8	4.1	3.6
2500	15.9	10.6	7.9	6.3	5.3	4.5	4.0
2750	17.4	11.6	8.7	7.0	5.8	5.0	4.4
3000	19.0	12.7	9.5	7.6	6.3	5.4	4.8
3250	20.6	13.7	10.3	8.2	6.9	5.9	5.2
3500	22.2	14.8	11.1	8.9	7.4	6.3	5.6
3750	23.8	15.9	11.9	9.5	7.9	6.8	5.9
4000	25.4	16.9	12.7	10.2	8.5	7.3	6.3
4250	27.0	18.0	13.5	10.8	9.0	7.7	6.7
4500	28.6	19.0	14.3	11.4	9.5	8.2	7.1
4750	30.1	20.1	15.1	12.1	10.0	8.6	7.5
5000	31.7	21.2	15.9	12.7	10.6	9.1	7.9
5250	33.3	22.2	16.7	13.3	11.1	9.5	8.3
5500	34.9	23.3	17.4	14.0	11.6	10.0	8.7
5750	36.5	24.3	18.2	14.6	12.2	10.4	9.1
6000	38.1	25.4	19.0	15.2	12.7	10.9	9.5
6250	39.7	26.4	19.8	15.9	13.2	11.3	9.9
6500	41.2	27.5	20.6	16.5	13.7	11.8	10.3
6750	42.8	28.6	21.4	17.1	14.3	12.2	10.7
7000	44.4	29.6	22.2	17.8	14.8	12.7	11.1
7250	46.0	30.7	23.0	18.4	15.3	13.1	11.5
7500	47.6	31.7	23.8	19.0	15.9	13.6	11.9

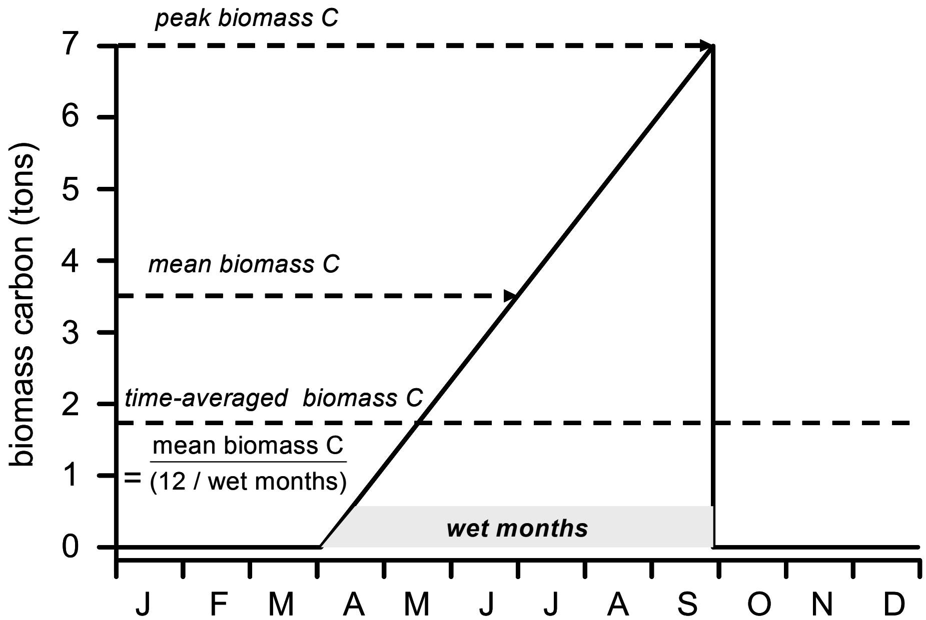

Figure 2. Peak biomass carbon, mean biomass carbon and time-averaged biomass carbon for a crop containing 6.0 t C where mean biomass C = 0.5 x (peak biomass C) and time-averaged biomass C = mean biomass C/(12 / wet months).

For example, if the growing season is 6 months during the year, the mean carbon content for the wet season is 3.5 t C (7.0/2). If the fields sit barren during the following dry six months, then the time averaged standing carbon stock is 1.75 t C throughout the year (see Figure 2). As the length of the growing season increases, so does the time-averaged biomass C. These equations also hold for intercrops or bimodal rainfall patterns if one combines the two annual crop yields in Table 2 and sums the total wet months. For example, if 3 t maize with a harvest index of 0.35 is grown in a five-month growing season in the first rains, and 1.5 t beans with a harvest index of 0.25 is produced during the three-month "short season", then:

Time-averaged biomass C = [(5.4 + 3.8) x 1.35) / 2] / (12 / 8) = 6.13 t C

Soil Carbon

Large amounts of carbon reside in the soil, but this C may not be as easily estimated as that in trees or crops. The measurement of soil organic carbon requires a laboratory where either wet digestion or dry combustion is performed. The results are expressed as grams of carbon per kilogram of soil (= parts per thousand) or as percent C (= parts per hundred). In general, soils range from about 5 to 25 g kg^{-1}, or 0.5 to 2.5% C. But this value, the carbon content, does not describe how much carbon resides in a particular field unless we know how much the soil weighs because some soils are heavier (more dense) than others. To convert from volume of soil to the weight of soil, we must also know the soil bulk density, the mass of soil per unit volume, and the depth of soil that is of interest.

$$\textbf{Soil C (t ha}^{-1}\textbf{) = C content (kg kg}^{-1}\textbf{) x bulk density (kg liter}^{-1}\textbf{) x (10 x soil depth (m}^{-2}\textbf{)) x 10000 m}^{2}\textbf{ ha}^{-1}\textbf{ x (0.001 t kg}^{-1}\textbf{)}$$

and this equation may be further simplified as:

$$\textbf{Soil C (t ha}^{-1}\textbf{) = C (kg kg}^{-1}\textbf{) x bulk density (kg l}^{-1}\textbf{) x soil depth (cm) x 100}$$

In general, soil bulk density ranges between 1.1 to 1.6 kg of soil per liter (= 1000 cubic centimeters) depending on the soil texture. Usually, the plow layer is considered to be 0 to 20 cm depth, and the root zone is from 0 to 50 cm depth. The amount of soil C in one hectare (tons C per ha where 1.0 ha equals 10,000 square meters) to a depth of 20 cm (= 200 per square meter), with a bulk density of 1.3 kg per litre (kg l^{-1}) and a carbon content of 15 g C per kg soil (= 0.015 kg C per kg soil) is calculated as:

$$\textbf{Soil C (t ha}^{-1}\textbf{) = 0.015 kg kg}^{-1}\textbf{x 1.3 kg l}^{-1}\textbf{ x 200 l m}^{-2}\textbf{ x 10000 m}^{2}\textbf{ ha}^{-1}\textbf{ x 1 t (1000 kg)}^{-1}\textbf{ = 39 t C per ha}$$

Again, this equation is rather complex for most non-scientists but tables may be constructed that simplify the mathematics. Table 3 provides the total soil organic carbon per ha in the top 20 cm and 50 cm horizons for soils of different textures (columns) and C contents (rows). In this case, it is not possible to generate an estimate independently of land area because the soil C stocks are a direct function of land area and soil depth; therefore, land managers who employ these tables are then expected to adjust their estimate based upon the land area under consideration.

An important feature of this table is its potential for interpolation, as all relationships are linear. For example, the C stock value of loamy clay or sandy clay is midway between the tabular values presented within the respective columns. Furthermore, the relationships within this table also may be applied to soil C fluxes as well as stocks. For example, if 10 g C per kg soil is lost due to soil erosion or intensive tillage, that carbon loss (or gain) may be estimated directly from the table.

A Shortcut Approach to Estimating Carbon Stocks

Lengthy mathematical discussion of these tables may distract from their overall purpose, to allow for rapid and accurate estimation of woody biomass and soil carbon stocks based upon minimum information. Carbon stocks which could not be “visualized” by land managers, development specialists or extensionists may now be quantified using these tables (Figure 3). Take for example the carbon gain resulting from an improved tree fallow producing 1000 trees per ha of 15 cm diameter and that increased total soil organic carbon in the loam by 0.8% C.

The woody biomass gain per ha is 0.033 t x 1000 = 33 t ha^{-1}. The soil C gain (for 8 g C per kg soil) is 35.2 t C ha^{-1}, yielding a system C estimate of 68.2 t C ha^{-1}. This value is best adjusted over time. For example, if the fallow interval is five years, then the C sequestration rate for woody biomass and total system C is 6.6 and 13.6 t ha^{-1}yr^{-1}, respectively.

Table 3. Soil organic carbon (SOC) (t ha^{-1}) in different textured soils resulting from changes in the SOC content (g kg^{-1} soil) at soil depths (0-20 and 0-50 cm).

soil C gain	loam	clayey Loam	clay	loamy sand	sand	loam	clayey loam	clay	loamy sand	sand
	bulk density (kg l^{-1})									
g C kg^{-1} soil	1.1	1.2	1.3	1.4	1.5	1.1	1.2	1.3	1.4	1.5
	soil C in 0-20 cm (t ha^{-1})					soil C in 0-50 cm (t ha^{-1})				
1	2.2	2.4	2.6	2.8	3.0	5.5	6.0	6.5	7.0	7.5
2	4.4	4.8	5.2	5.6	6.0	11.0	12.0	13.0	14.0	15.0
3	6.6	7.2	7.8	8.4	9.0	16.5	18.0	19.5	21.0	22.5
4	8.8	9.6	10.4	11.2	12.0	22.0	24.0	26.0	28.0	30.0
5	11.0	12.0	13.0	14.0	15.0	27.5	30.0	32.5	35.0	37.5
6	13.2	14.4	15.6	16.8	18.0	33.0	36.0	39.0	42.0	45.0
7	15.4	16.8	18.2	19.6	21.0	38.5	42.0	45.5	49.0	52.5
8	17.6	19.2	20.8	22.4	24.0	44.0	48.0	52.0	56.0	60.0
9	19.8	21.6	23.4	25.2	27.0	49.5	54.0	58.5	63.0	67.5
10	22.0	24.0	26.0	28.0	30.0	55.0	60.0	65.0	70.0	75.0
11	24.2	26.4	28.6	30.8	33.0	60.5	66.0	71.5	77.0	82.5
12	26.4	28.8	31.2	33.6	36.0	66.0	72.0	78.0	84.0	90.0
13	28.6	31.2	33.8	36.4	39.0	71.5	78.0	84.5	91.0	97.5
14	30.8	33.6	36.4	39.2	42.0	77.0	84.0	91.0	98.0	105.0
15	33.0	36.0	39.0	42.0	45.0	82.5	90.0	97.5	105.0	112.5
16	35.2	38.4	41.6	44.8	48.0	88.0	96.0	104.0	112.0	120.0
17	37.4	40.8	44.2	47.6	51.0	93.5	102.0	110.5	119.0	127.5
18	39.6	43.2	46.8	50.4	54.0	99.0	108.0	117.0	126.0	135.0
19	41.8	45.6	49.4	53.2	57.0	104.5	114.0	123.5	133.0	142.5
20	44.0	48.0	52.0	56.0	60.0	110.0	120.0	130.0	140.0	150.0
21	46.2	50.4	54.6	58.8	63.0	115.5	126.0	136.5	147.0	157.5
22	48.4	52.8	57.2	61.6	66.0	121.0	132.0	143.0	154.0	165.0
23	50.6	55.2	59.8	64.4	69.0	126.5	138.0	149.5	161.0	172.5
24	52.8	57.6	62.4	67.2	72.0	132.0	144.0	156.0	168.0	180.0
25	55.0	60.0	65.0	70.0	75.0	137.5	150.0	162.5	175.0	187.5

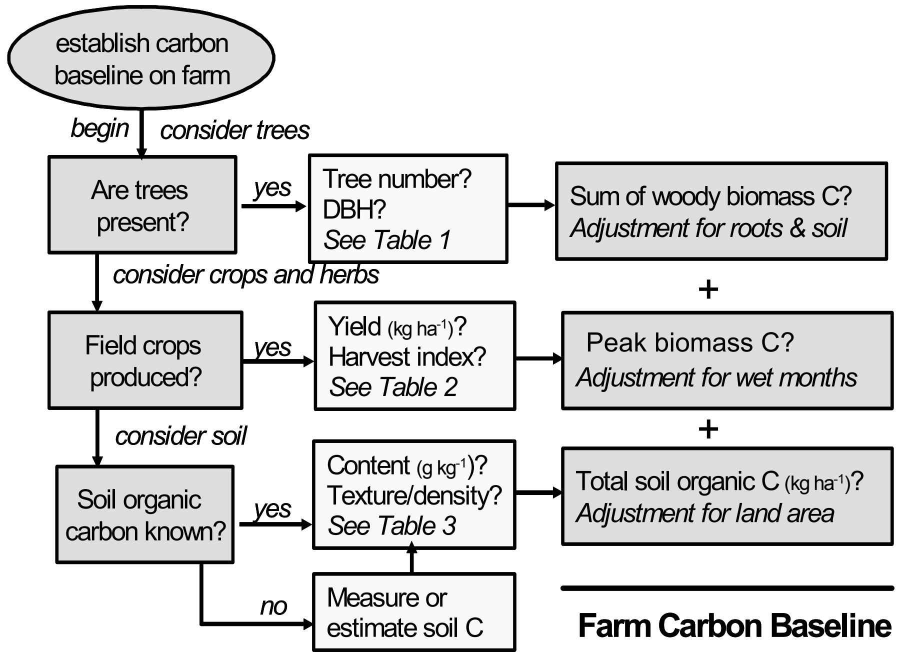

Figure 3. A stepwise approach to estimating a farm carbon baseline that considers trees, crops and soil that may be adjusted for different land areas.

It must be emphasized that these tables are intended to assist a wider cross-section of the land management and environmental communities to become involved in the estimation of carbon stocks, and in some ways are over-simplified. Table 1 is based upon a preliminary assumption of a single widely applicable allometric equation predicting aboveground tree biomass and this table could be better refined for more applicable DBH size categories and different tree species and vegetation zones. Table 2 presents yield increments of 500 kg and assumes that one is aware of the harvest index for a given crop. Table 3 assumes that the range of interest for soil C stocks is 25 g C kg soil^{-1} and that five textures adequately cover the range of soil texture conditions.

Figure 3 illustrates how to use the information in this chapter to estimate the carbon in a field or on your farm. To do this, one must know the number of trees and their diameters, crop yields and have an estimate of the harvest index, the soil organic C content and the soil bulk density. Get a paper and pencil (or a good calculator) and then refer to Table 4 to compile a farm or field carbon baseline, the carbon gains from tree planting and the value of that carbon. Table 4 is completed using the following procedure:

1. **Step 1. Establish baseline: tree biomass C.** This section of the form is intended for completion before the initiation of a carbon offset project, or may be completed by comparing a cropland adjacent to tree planting, assuming that

past land use and soil are representative. Enter the DBH and number of trees that fall into up to three different size categories and refer to Table 1a to identify the tree biomass C for each category by matching the tree diameter (columns) and number of trees (rows). Additional categories may be included on a separate sheet if necessary. Sum the categories to obtain the Total Tree Biomass C and enter this value into the far right column of Table 4.

2. **Step 1. Crop Biomass C.** Enter the yield and harvest index for up to two crops grown either sequentially within the same year or as intercrops. And identify the peak C for each by matching the harvest indices (columns) and crop yield (rows) from Table 2. Sum these values to obtain the Total peak crop C and enter this value into the far right column of Table 4. Time-average this value by including the total number of wet months.

3. **Step 1. Soil C.** This section requires that the soil be analyzed for C and the results expressed as g C per kg soil (= 0.1 x C%). Based on either soil texture or bulk density, identify the appropriate column and match this with the appropriate C content in Table 3 to obtain the value for total soil C (t C per ha) and enter it into the far right column of Table 4.

4. **Step 1. Total system baseline C.** Calculate this value as the sum of total tree, time-averaged crop and soil C and enter it into the far right column. This value is the baseline C.

5. **Step 2. Project C gains: Tree and Soil C.** This part of the form is intended to be completed at regular intervals (e.g. once a year) after the planted trees are established and growing. Enter the tree numbers and diameters and identify their C contents, this time using Table 1b, which also considers C gain in the soil beneath the trees.

6. **Step 2. Intercrop C.** Include the time-averaged C content contained in intercrops (Table 2), understorey or cover crops and adjust the value by wet months. Many cover crops lack "yield" so the biomass C must be obtained through destructive sampling.

7. **Step 2. Project C gains.** Sum the tree and crop C values. This is the unadjusted Total C gain.

8. **Step 3. Net C gain.** Calculate this value by subtracting the baseline value, but do not include the baseline soil C (baseline tree and crop C, but not soil C) and enter in the far right column. Calculate the value of this C by multiplying it by the C price, usually $10 per t C.

Table 4. Calculating C baseline, project C gains and net carbon value.

Step 1: Establish baseline C status in project area
Tree biomass C (from Table 1a)
Tree category 1 DBH _________ number __________ carbon ______________
Tree category 2 DBH _________ number __________ carbon + ____________
Tree category 3 DBH _________ number __________ carbon + ____________
Total tree biomass C (TTBC) = ∑ categories 1-3 = _________ **t C**

Crop biomass C (from Table 2)
Crop 1 _______________ yield ______ harvest index _____ peak C ______________
Crop 2 _______________ yield ______ harvest index _____ peak C + ____________
Total peak crop C (TPCC) = __________ t C
Time-averaged crop C (TACC) = (0.5 x (TPCC)) / (12 – wet months) = __________ **t C**

Soil C (from Table 3)
Soil carbon content (g C kg^{-1} soil) __________
Texture _________________ or bulk density ___________ kg l^{-1}
Soil depth [} 20 cm [} 50 cm) Soil C (from Table 3) ___________ t ha^{-1}
Land area ________________ ha
Total soil C (TSC) = Soil C (t ha^{-1}) / land area (ha) = _______________ **t C**
Total system baseline C (TSBC) = TTBC + TACC + TSC = _______________ ***tC***

Step 2: Estimate C project gains through tree planting and intercropping
Tree biomass and soil C gains (from Table 1a)
Tree category 1 DBH _________ number __________ carbon _____________
Tree category 2 DBH _________ number __________ carbon + ___________
Tree category 3 DBH _________ number __________ carbon + ___________
Total tree and soil C gains (TSCG) = ∑ categories 1-3 = _________ **t C**

Intercrop biomass C (from Table 2)
Intercrop 1 ______________ yield ______ harvest index _____ peak C _____________
Intercrop 2 ______________ yield ______ harvest index _____ peak C + ___________
Total peak crop C (TPCC) = _________ t C
Time-averaged crop C gain (TACG) = (0.5 x (TPCC)) / (12 – wet months) = _________ **t C**
Total project C gain (TPCG) = TSCG + TACG = _________ ***tC***

Step 3: Calculate net project C and value
Net project C (NPC) = (TPGC – (TSBC – TSC))
TPGC _____________ t C
TSBC - _____________ t C
TSC - _____________ t C
NPC = _____________ **t C**
Net Project C value = Net project C (t) x C price ($ t^{-1})
C price ($ t^{-1}) x _____________ $ t^{-1}
Net Project C value = _____________ **$**

Cultivated parklands offer dual opportunity for crop production and terrestrial carbon storage as demonstrated by groundnut growing in mixed evergreen parkland (above) and with deciduous *Faidherbia albida* (below).

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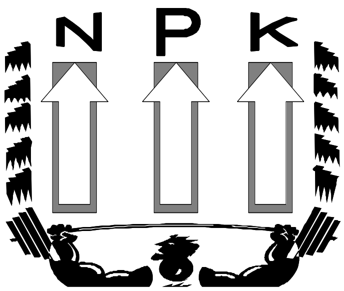
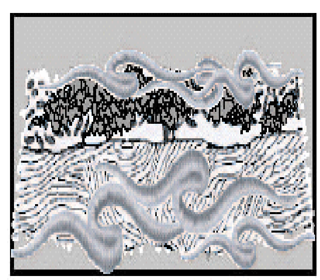
Part 2

Composting Technique





Organic Resource Management in Kenya:
Perspectives and Guidelines
Edited by C.E.N. Savala, M.N. Omare
& P.L. Woomer. FORMAT, Nairobi. 2003

Chapter 8

A Scientific Perspective on Composting

John K. Lekasi, Keziah W. Ndung'u and Mary N. Kifuko

From a scientific perspective, composting is the partial decomposition and stabilization of heterogeneous organic substances by a mixed microbial population under optimum conditions of moisture, temperature and aeration. Compost is composed of fairly homogeneous, stable organic matter with high molecular weight and is free of pathogens and weeds seeds. In nature, dead organic materials undergo several processes of microbial transformation according to substrate composition and physical environment. Composting requires that the process be mostly aerobic so that the organic matter is partially mineralized and humified. In order to produce suitable compost for agriculture, the composting process must be controlled, particularly through the choices of substrate, moisture content and aeration. Many of the different composting systems that have been developed have utilized this basic principle in their design (Table 1).

Many agricultural wastes contain sufficient organic material for composting. These include solid urban waste, food factory waste and other industrial by-products, sewage sludge, agricultural residues and domestic waste. Some of these wastes require careful separation of organic matter from inert materials such as glass, plastic and metals. The organic fraction of the waste is quite heterogeneous and if introduced directly into the soil, it will not perform in as predictable a manner. Composting radically transforms various organic substances, it mineralizes the readily assimilable materials and humifies them into more complex compounds. Stated more simply, composting is an elegant, but rather complex process that blends different ingredients into a uniform useful product.

Stages of Composting

The composting process is characterized by a period of rapid decomposition and temperature accumulation followed by cooler, slower decay of the remaining organic substrates. The rate of decomposition can be increased by stacking the materials in a pile to a height of 1.0 to 1.5 m, however, taller stacks must be more

Table 1. A summary of composting systems for organic wastes which are also utilized for industrial composting (adapted from Bertoldi *et al.*, 1985).

Open Systems

- Turned pile (commonly used in Kenya)
- Static pile
  - air suction
  - air blowing
  - alternating ventilation (blowing and suction)
  - air blowing in conjunction with temperature control

Closed Systems

- Vertical reactors
  - continuous
  - discontinuous
- Horizontal reactors
  - static
  - with movement of material

frequently turned to facilitate rapid decomposition and prevent the formation of unwanted anaerobic by-products.

The temperature in the compost pile will rise due to enhanced microbial (fauna and flora) heat production resulting from heterotrophic oxidation and also because of the relatively slow heat transfer to the environment. Other important aspects of composting include the C/N ratio of the organic substrates, other nutrient concentrations, surface area and acidity. Microorganisms, primarily bacteria, actinomycetes and fungi, use the organic materials as a source of energy and nutrients, producing heat, gases and stabilized organic matter. Microbial populations change with temperature during the mesophilic (20-40 ^{0}C) and the thermophilic stage (>40 ^{0}C) then back to ambient during the curing stage (Figure 1).

The mesophilic stage is a preparatory state that initiates the decomposition process and brings the compost into temperature ranges that are suitable for thermophiles. This stage is achieved by the rapidly decomposing and readily-available compost substrate. In the mesophilic stage, temperatures rise rapidly to high levels up to 65^{0}C.

The thermophilic stage is necessary to ensure stabilization and to

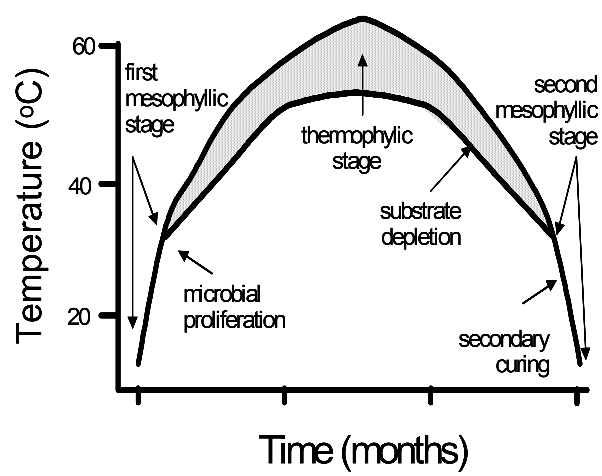


Figure 1. The stages and major events in composting.

pasteurize the compost, eliminating many harmful organisms. This stage may last a number of days depending on how well oxygen is supplied to the pile and the quality and quantity of the substrate.

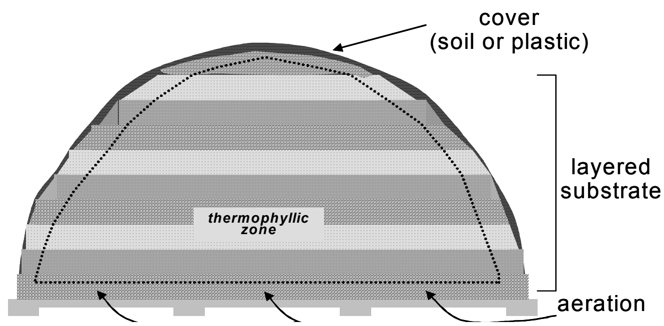


Figure 2. The principle elements of a compost pile, including the interior thermophilic zone.

Temperatures vary in a compost pile with the outer layer having a lower temperature compared to the inner zone of high temperature (Figure 2). To ensure even decomposition and better aeration, periodic turning is necessary. Enteric pathogens such as *Salmonella* spp., normally survive less than one hour once the compost enters the thermophilic stage. Other noxious organisms such as weed seeds and parasites eggs may be more durable but are often eliminated or greatly reduced during composting. Pasteurization is one reason composting is a popular waste treatment. During the stabilization stage, substrate becomes a limit to microorganisms. The compost pile temperatures fall back to mesophilic stage range and reestablishment of the mesophilic organisms occurs. During slower processing, the compost may become colonized by soil fauna, such as earthworms or beetles, and these organisms assist in curing.

Properties of compostable materials

The important physical properties of materials intended for composting are particle size and moisture content. Particle size affects oxygen movement into and within the pile, as well as microbial and enzymatic access to the substrate. Proper balance in the particle size should be maintained. If too large, the organic materials should be chopped into smaller pieces. On the other hand if too small, the organic materials should be mixed with a bulking agent (eg. wood chips or tree bark). The optimum moisture content for composting is 40 to 60%. Water interferes with oxygen accessibility, slowing the rate of composting while too little water hinders diffusion of soluble molecules and microbial activity.

The chemical characteristics of the organic residues may be considered in terms of nutrient quality and quantity. The ranges of elemental composition for some residues suitable for composting are shown in Table 1. The relative quantity of the C, N, P S and other nutrients is important, but keep in mind that mineral nutrients are largely concentrated during composting as the carbon compounds are oxidized by microorganisms. Substrate quality is also influenced by secondary compounds, such as lignin and polyphenol, that are more recalcitrant to decomposition and may restrict nitrogen availability through proteins-binding.

Table 2. Nutrient concentrations of selected dry compostable materials

Composting material	N	P	Ca	K	Mg	C/N
	---------------------------- (%) ---------------------------					
Chicken manure	4.5	0.8	1.8	0.7	0.4	7
Cattle manure	1.5	0.5	1.0	0.6	0.3	18
Grass cuttings	1.2	1.1	<0.1	2.0	0.1	27
Alfalfa	2.4	0.2	1.4	1.8	3.9	15
Maize stover	0.9	0.1	0.4	1.2	0.1	42
Wheat straw	0.6	0.1	0.6	1.2	0.1	90
Mixed green weeds	2.3	0.3	0.1	1.3	<0.1	21

Although different compostable substrates often begin with widely divergent nutrient contents, the quality and quantity of the nutrient converge as composting proceeds. Metabolic processes also affect the pH of the compost. Deamination of proteins rapidly increases the pH due to ammonia. Conversely, production of organic acids during the decomposition of carbohydrates and lipids decreases the pH. On average, pH of inputs is somewhat acidic while finished compost is near neutral.

The relative quality and quantity of the organic residues affects the rates of composting and the characteristics of the finished products. For example, when the C/N ratio of the organic matter is about 25, metabolism of the organic material may proceed rapidly with a high degree of efficiency of N assimilation into the microbial biomass. A narrower C/N ratio may lead to loss of N from compost through ammonia volatilization. Wider C/N ratios (>40) promote immobilization of available N in the compost slowing the rate of decomposition. Therefore, addition of mineral N and P in the process of fortification can enhance rapid decomposition and enrichment of low quality residues.

Assessing Compost Maturity

Compost most suitable for agriculture should be well cured and mature. The basis for efficient preparation of compost hinges upon recognizing differences in quality and adjusting application rates and timing of application accordingly. At present, as well as the traditional tools for investigating decomposition (C:N ratio, temperature, humidity) other methods are available from the most sophisticated, which may be employed only in well-equipped laboratories, to the most basic which can be adapted to the immediate needs of a smallscale composting operation.

A study was conducted in Maragua District in Kenya to identify simple methods of rapidly assessing the quality of composted cattle manure (Lekasi *et al.*, 2003). Several discernible characteristics could be used to judge maturity and quality of these composts including texture, colour, smell and biological activity.

Table 3. Chemical characteristics of some mature compost entered into the FORMAT Compost Contest in 2002.

Source	N	P	K	Ca	Mg	C	polyphenol	lignin
	----------	----------	----------	----------	%	----------	----------	----------
C. Othiambo	1.6	1.1	1.1	3.5	1.9	41	3.2	8.4
K.W. Kamau	1.2	0.3	2.0	3.8	0.5	35	4.2	10.7
T. Kiroga	0.3	0.2	0.4	0.3	0.2	34	0.3	7.9
C.M Ameka	0.6	0.2	0.5	0.1	0.3	38	0.3	8.3
E. Simiyu	0.4	0.1	0.3	trace	0.2	32	0.1	0.7
M.K Ouma	2.0	0.6	0.2	1.8	0.3	32	0.6	13.1
J Kosgey	1.5	1.0	0.8	3.0	0.7	33	2.0	5.5
F.W. Wafula	0.8	0.3	0.6	0.1	0.3	31	0.4	7.0
E.K. Telewa	1.5	0.5	1.4	0.6	0.6	38	3.2	15.1
J. Chirchir	2.5	0.6	0.7	3.3	0.6	41	2.3	12.2
P.S. Watua.	2.6	0.7	2.4	1.6	0.7	55	3.8	22.2

When compost texture was considered, coarse materials become finer over time until a fine, loamy material is produced. Changes in the colour of the compost can also tell its quality and maturity. The assumption for this parameter is that less decomposed material consists of a more heterogeneous mixture of animal feaces and other organic materials that also differing in color, resulting in a mottled appearance. As decomposition progresses, such material becomes more homogeneous, appearing as uniform dark brown or black at maturity. When composting cattle manure, sewage sludge and some industrial wastes, the smell can indicate the stage of composting. Fresh animal manure and wastes have a strong smell of ammonia and putrefaction during the early stages of decomposition. Mature compost is expected to have only a slight ‘earthy’ and inoffensive smell.

Biological activity is another useful indicator of compost maturity. The presence of macrofauna in maturing compost, particularly earthworms and grubs, serves as an indication of the stage of compost maturity because time is required for these invertebrates to re-colonize the substrate following the thermophilic stage. The fauna and flora of compost heaps changes with time, both increasing and decreasing with maturity depending on the group of organisms. For example, earthworm activity might increase to a maximum and then decline towards maturity, while other soil fauna and fungi demonstrate peak activity at other times. Grubs (beetle larvae) are often in mature compost heaps. A clear understanding of changes of these different domains in respect to the composting process and stages can, therefore, be used in combination to predict the quality and maturity of compost to a fairly accurate extent.

Maximizing Decomposition during Composting

In composting for waste management purposes, odour control and cost effectiveness are both served by maximizing the rate of decomposition. The composting “ecosystem” tends to become self-limiting by excessive accumulation of metabolically-generated heat, leading to inhibitively high temperature. The threshold to significant inhibition is approximately 60 ^{o}C, and inhibition increases sharply at higher temperatures. Unless controlled through deliberate venting, composting masses may reach as much as 80 ^{o}C, at which point the rate of decomposition becomes extremely low. Prolonged temperature exposure literally pasteurizes the decomposing substrate, destroying many harmful organisms.

A practical means of removing heat from the composting mass is through ventilation. The main ventilation-association mechanism of heat removal is the vaporization of water. Ventilation also supplies O_2 for aerobic decomposition. During composting, the rate of heat generation varies with time. At the small-scale level, occasionally turning the heaps serves this purpose very well. In the most advanced commercial composting, ventilation is achieved by using fans that are mechanically controlled with temperature and moisture sensors. When an initial substrate contains a large proportion of water, as with manure slurries or sewage sludge, composting also serves as a effective means of removing the excess water in addition to producing quality organic fertilizer for use in agricultural production.

Conclusion

Fortunately most of the composting science is intuitively considered by those with experience. Mixing and layering inputs results in a wide range of nutrients and substrates. Covering the compost pile reduces water loss and conserves heat. Placing the pile on a platform and periodic turning facilitates aeration. Composting is one example where the considerations of science are well covered by those who approach it as an art.

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Organic Resource Management in Kenya:
Perspectives and Guidelines
Edited by C.E.N. Savala, M.N. Omare
& P.L. Woomer. FORMAT, Nairobi. 2003.

Chapter 9

Producing Fortified Compost from Crop Residues

Keziah W. Ndung'u, Mary N. Kifuko and J. Robert Okalebo

Many African countries continue to require increasing amount of food aid (World Bank, 1996) because their agricultural production does not match population growth. This is most evident in countries where population growth is very high and yet soils tend to be highly weathered and have low inherent fertility (Smaling *et al.,* 1997). In Kenya, farmers realize the need for soil amendments by using available resources such as farmyard manure, poultry wastes and piggery effluent (Woomer and Swift, 1994), however, the quantity and quality of these materials limit their use (Delve, 1998). In addition, farmers appreciate the use of mineral fertilizers but their ever-increasing costs often prohibit their application at recommended rates (Heisey and Mwangi 1996). In some areas, crop residues such as wheat straw and maize stovers are left on the land but their decomposition rate is very low because of the high C:N ratio. These materials accumulate in very large amounts and are difficult to dispose. For example, in Uasin Gishu and Trans Nzoia districts of Kenya, yields of maize stover and wheat straw range from 4 to 15 t ha^{-1} (Muasya, 1996). Management of these residues includes incorporation back into the soil, feeding residues to livestock or burning (Lwayo *et al*., 2001). The Faculty of Agriculture at Moi University has developed a technology to recycle plant nutrients from wheat straw and maize stover. This technology involves fortification of these residues with nitrogen (N) and phosphorus (P) fertilizers to reduce losses from the composting process.

Procedure for Fortification of Organic Residues

Low quality organic materials such as maize stover or wheat straw with a wide C/N ratio are suitable for preparing fortified compost. The procedure for fortifying such organic materials is:

1. Chop crop residues into 30-45 cm lengths in order to increase their surface area.

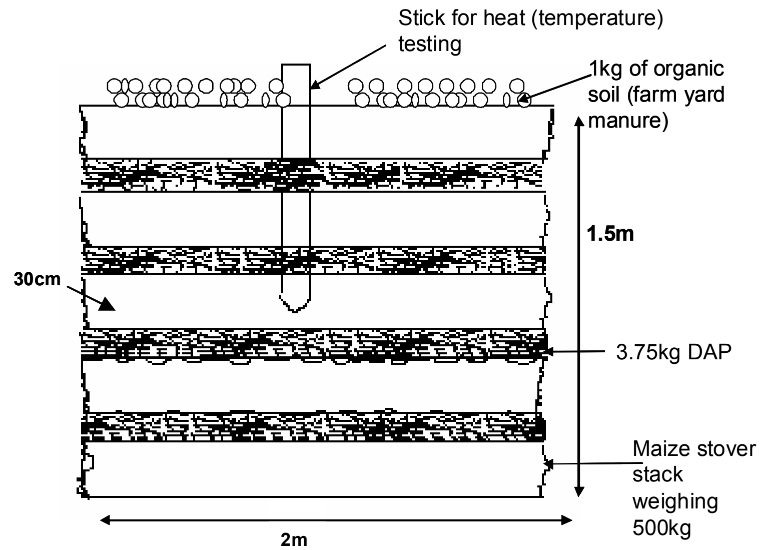

Figure 1. Fortified compost heap set up using the Moi University fortification method

2. Spread the chopped material in five successive layers of 30 cm high by 2.0 m wide into windrows 25 m long (≈ 500 kg in each layer).
3. At every 30 cm layer, evenly broadcast 3.75 kg DAP (or any other nitrogen-bearing fertilizer) for fortification lowering the C:N ratio from 80 to about 12.
4. Apply 1.0 kg of organic soil uniformly as a "starter inoculant". Farmyard manure, sugarcane mill filter mud or pond sediments are suitable materials for this purpose.
5. Apply 20 litres of water at the same height to enhance dissolution of fertilizers and to moisten the stover for microbial activity.
6. Repeat steps 1 to 5 until the 25 m windrows are 1.5 m in height (Figure1).

Turning the Compost

Turning compost is important as it ensures proper mixing, wetting, aeration and decomposition. The compost heap is allowed to settle for one month, and then turned using pitch forks. Material on the top of the heap and along the edges is laid on the ground first, followed by the materials in the middle of the heap. Materials at the bottom are then placed at the top of the heap. It is recommended to sprinkle 20 liters of water on the heap during turning particularly when conditions are dry. Compost turning is continued until the heaped materials turn dark gray. Biological activity is monitored by pushing a stick into the middle and sides of the stack. The stick is pulled periodically and felt by hand for any temperature changes. For example, eight days after compost piling, much heat is generated from the center of the heap and the stick driven in the compost should indicate the same. This is an

Table 1. Sources and characteristics of commonly available crop residues, compost and manure among smallhold farmers in western Kenya.

Material	Nutrient content			
	Organic matter	N	P	K
	%			
Maize stover	-	0.89	0.08	2.78
Bean trash	-	1.20	0.13	2.06
Banana trash	-	0.83	0.06	4.54
Compost (Ben Mutambo, Kanduyi)	39.6	1.17	0.24	0.53
Slaughter house manure (Bungoma)	44.7	1.65	0.59	0.56
FYM[1] (Protus Opicho, Bungoma)	21.3	0.89	0.19	0.82
FYM (Mary Wangila, Webuye)	42.8	1.61	0.54	2.52
FYM (Boniface Wamalwa)	13.1	0.39	0.11	0.40
Compost (Peter Simiyu, Siritanyi)	19.6	1.22	0.26	0.86
Fortified compost (Moi University)	52.0	2.20	0.42	1.40

[1]FYM = farmyard manure

indication of biological activity in the compost (e.g. the thermophilic stage). Composting requires 4 to 6 months and at maturity and about 1900 kg of fortified compost is produced. Mature compost is odourless and has a fine texture. When the stick for testing temperature is driven into the heap, it should be cool (at ambient temperature) indicating that all the potentially harmful organisms and by-products have been eliminated.

Chemical Properties and Use

A comparison between fortified compost and a number of crop residues and organic manures appears in Table 1. Fortified compost is consistently among the highest organic resources in terms of nitrogen (2.2%), phosphorus (0.42%), potassium (1.42%) and organic matter (52%).

Significant maize grain yields from fortified compost applied at 2 t ha^{-1} were observed as compared to the control (Figure 2). Fortified compost provided 4 t ha^{-1} of grain yield, which was comparable to DAP at 20 kg P per

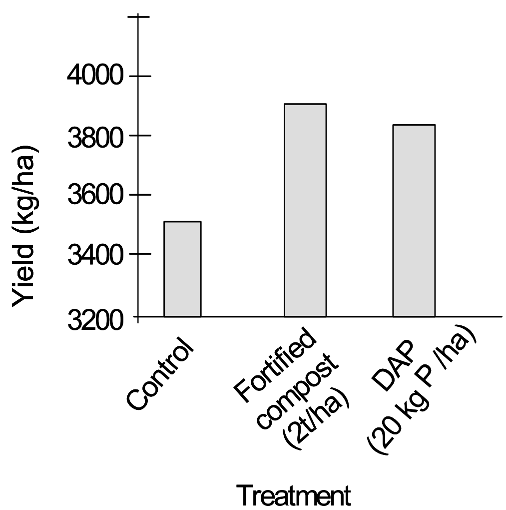

Figure 2. Effect of fortified compost, conventional compost and DAP fertilizer on maize yield in Uasin Gishu, 1998.

ha, probably due to the increased N and P release from the compost. Non-fortified compost applied in conjunction with DAP at 20 kg P ha^{-1} resulted in reduced yields, demonstrating better agronomic effectiveness of fortified compost compared to an alternative allocation of the same inputs. In areas with large quantities of maize stover, fortifying these residues is an alternative to burning.

Conclusion

There is potentially a large number of farmers in western Kenya who could benefit from the use of fortified compost to improve their overall crop yields and better utilize post harvest residues. The technology offers potential to smallhold sugar outgrowers in western Kenya as well as large-scale and wheat producers in the Rift Valley. The mound and windrow composting technique described in this chapter is appropriate for materials other than maize stover and wheat straw and when higher quality materials such as manure, tree prunings and grass cuttings are being composted, there is little or no need to fortify them with mineral fertilizer. However, lack of technical know-how to make and use compost is lacking. Farmers should be trained on how to prepare fortified compost. On-farm trials should be conducted at multiple locations to enable as many farmers as possible to learn how to make and use fortified compost. Socio-economic factors, such as labor availability or lack of space, that hamper the adoption of this technology should also be identified and solutions to these problems offered.

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Edited by C.E.N. Savala, M.N. Omare & P.L. Woomer. FORMAT, Nairobi. 2003

Chapter 10

Preparing Compost and Silage from Water Hyacinth

Robert N. Muzira, Alice Amoding and Mateete A. Bekunda

Water hyacinth, *Eichhornia crassipes* (Mart), is an aquatic plant from Tropical America belonging to the family *Pontederiaceae*. The mature plant consists of long fibrous roots, rhizomes, buoyant petioles, stolons, leaves, inflorescence and fruit clusters. The inflorescence bears between 6 and 120 lily-like violet and yellow flowers. The fruit is a capsule, containing up to 450 seeds. Water hyacinth is a problem in water bodies because of its dense strands and rapid proliferation. It is very efficient in utilizing aquatic nutrients and solar energy for profuse biomass production (Amoding *et al*., 1999).

Depending on the time of the year and location, the plants double in number and biomass every 6 to 15 days. Between 400 and 1700 tonnes fresh weight are produced per hectare per year. Given that the dry weight is about 5-7% of fresh weight, one hectare yields between 20 and 120 tons of dry water hyacinth per year, containing nitrogen (N), phosphorus (P) and potassium (K) as well as other plant nutrients. It makes sound economic sense to utilize the water hyacinth as an organic input to soils. Water hyacinth waste provides mulch that assists in both water retention and weed suppression. When composted with a variety of materials such as animal manure, phosphate rock and wood ash, its nitrogen content increases making it more suitable for the production of higher-value crops or as an ingredient for potting mixtures (Table 1).

Compost is a mixture of the remnants of degraded plant material and the by-products of the degrading organisms. It is produced through a process referred to as "composting". Several factors influence this process and its rate. Substrate size is important because smaller plant material degrades more rapidly due to its higher surface area. Initially, temperature affects the types of organisms that colonize the compost pile and the rate of their metabolism but later, heat released by microbial decomposition determines the compost's peak temperature. Composting proceeds more rapidly during warmer months and slower during the cooler months. The placement and dimensions of the compost may increase decomposition rates due to better aeration and moisture conservation. Alternatively, poorly drained or drier conditions slow the rate of compost production.

Table 1. Changes in the chemical characteristics of composting water hyacinth.

Time (weeks)	pH	N	P	K	Ca	Mg
		--------------------------------Nutrient content--------------------------------				
		------------------------------%------------------------------				
0	-	1.9	0.3	1.7	2.7	0.3
2	7.6	3.1	0.3	1.1	0.5	0.3
4	8.0	2.8	0.2	0.7	0.7	0.3
8	8.9	3.0	0.2	0.6	0.7	0.2
12	8.5	3.4	0.3	0.9	0.9	0.3

The following procedure describes a pit composting technique that is appropriate for water hyacinth and other course-textured materials. Pit composting generally requires more time than raised (piled) composts but it requires less initial investment and better conserves moisture.

Preparing Pit Compost

1. Prepare a pit 1.5 m long x 1 m wide x 1 m deep and line the sides and bottom with plastic sheeting.
2. Obtain 5 to 10 t of fresh water hyacinth plants, place them into the pit, spread 10 to 20 kg of cattle manure across the top as a biological activator and cover the pit with plastic sheeting.
3. After 1 month, uncover the pit and mix with a pitchfork. By this time, plants are light brown, leaves are decomposing and stems and roots are more-or-less intact
4. After another month, uncover and mix with a pitchfork again. Material is now dark brown, shoots are decomposed and the corms and roots are beginning to fragment. Replace plastic cover.
5. After one more month, uncover and remove finished compost from the pit, spread, break apart large "clods" and dry.
6. After drying, the dark coloured compost is ready for application to soil.

Figure 1. Well-composted water hyacinth without any additives becomes black mass with fully disintegrated tissues. When mixed with other organic materials, it becomes dark brown.

Fortifying Compost with Rock Phosphate

1. Retrieve well-composted water hyacinth material from the pit
2. Spread the material on a plastic sheet or concrete floor to drain out excess water
3. When it is still moist, pass the compost through a 5 or 10 mm screen
4. Put the screened material on a plastic sheet and mix with 5% ground phosphate rock
5. For larger volumes use a cement mixer or oil drum to mix the material
6. Pack the mixed product in convenient bags, for example 3, 5 or 10 kg bags.
7. Store secured bags of the compost in a dry place until the time of application

Preparing Potting Mixtures from Water Hyacinth Compost

1. Partially dry the water hyacinth compost
2. Separately pass the compost, coarse sand and charcoal granules through a 5 mm screen
3. Put the screened compost, sand and charcoal on plastic sheet; and mix with powdered phosphate rock and crushed bone in the ratio of 20:10:10:1:1
4. For large volumes use a cement mixer or oil drum to mix
5. Pack the mixed product in storage bags

Using Compost and Potting Mixtures

Remember that compost is great for improving the condition of your soil. With compost you will get better crops and healthier plants. Now is the time to start using this wonderful material.

- *In the garden.* Spread the compost on the soil about 3 to 5 cm thick and incorporate it into the soil before planting.
- *To existing garden beds.* Place the compost around the existing plants as top dressing mulch. If you wish, dig the compost into the soil being careful to avoid disturbing plant roots.
- *As a potting mixture.* You can make great potting mixes for indoor and outdoor plants using compost. Try mixing compost, soil, sand and manure for a rich well-drained potting mixture (as described above).
- *Remember your friends.* Whenever you have too much compost, give some away to friends.

Preparing Silage

Scientists in the Faculty of Agriculture at Makerere University in Uganda have developed a simple method to prepare nutritious feed for livestock from water hyacinth that promises to commercialize this use. Silage is made by combining wilted water hyacinth with 10% maize bran and allowing the mixture to ferment for 20 days. Silage is produced by the activities of naturally-occurring bacteria that convert some of the plant sugars into organic acids that preserve nutritional qualities. The finished product is golden brown in colour, sweet smelling, readily acceptable to cattle and may be stored for long periods without loss of quality. The following procedure produces silage useful as a feed supplement (Lindsey and Hirt, 1999; Woomer *et al*., 1999).

1. Recover. Fresh water hyacinth plants are recovered from a clean water body and the roots removed and dried for use as an ingredient in potting soil. Do not use water hyacinth taken from polluted waters as it may contain toxic heavy metals.

2. Chop dry and mix. The shoots, consisting of leaves, petioles (stalks) and rhizome (base), are chopped into large pieces and air dried to about 80% moisture. Drying a large pile requires about two days and periodic mixing until the leaves and stalks are just beginning to wilt. Add 7.5 kg of maize bran to 42.5 kg of water hyacinth and mix in a large tray or on a rolling tarpaulin until the maize bran uniformly coats the chopped water hyacinth. This mixture may be prepared by combining 11 parts water hyacinth to 1 part maize bran. Maize bran will not adhere to the chopped water hyacinth if it is too dry. If this

Figure 2. Water hyacinth utilization in Uganda. Fresh water hyacinth (upper left) is collected and transported (lower left) for processing into silage (upper right) and compost (lower right).

problem occurs, sprinkle 2 litres of water on the chopped water hyacinth and maize bran and re-mix the materials.

3. Bag and store. Tightly pack the mixture into a large, medium gauge, air-tight plastic bag and close bag with string or wire. Squeeze out any remaining air when tying the plastic bag. Stack 3 to 4 bags in an upside-down position. This minimizes the entry of air from any tears in the plastic bags. Place the bags away from the sun or cover with a non-transparent sheet. It is normal for the bags to feel warm to the touch after three days or so. The contents will turn from green to olive to brown during the first week.

4. Feed. The silage is ready for use after 14 to 20 days and can be stored for several months without loss of quality. Very little weight loss occurs during silage fermentation or storage. Use silage as a feed supplement, not a complete ration. Poultry and ducklings perform poorly with this feed but cattle, goats, pigs and rabbits are well suited to it.

The silage is approximately 20% dry matter. The dry matter contains 13% crude protein, 20% acid detergent fibre, 0.4% calcium and 0.8% phosphorus. Silage may be prepared by substituting molasses for maize brain but the resulting feed is lower in dry matter and crude protein. The silage resulting without addition of either maize bran or molasses has poor nutritional value and storage characteristics. The scientists at Makerere are currently investigating the use of sweet potato vines and urea as additives as well as preparing the silage on a larger scale in brick-lined pits. Preparing compost or silage from water hyacinth offers many advantages (Woomer *et al*., 1998). It provides incentive for communities to recover water hyacinth from the shoreline, eliminates the problem of waste disposal and reduces the need of growing or collecting other green manures and fodders.

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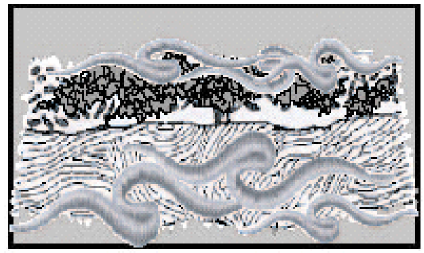

Chapter 11

Using Earthworms to Make Vermicompost

Canon E. N. Savala

Epigeic earthworms do not inhabit the soil rather they live in and consume surface litter. These worms are domesticated and, when fed plant and animal wastes, they produce vermicompost, a process that has many advantages over conventional composting. This technology serves both social and environmental goals of sustainable agriculture and is widely employed in India, Australia, New Zealand, Cuba and Italy (Ceccanti and Masciandaro, 1999), but seldom in Africa. Epigeic earthworms do not burrow into the soil and are therefore more easily contained within vermicomposting systems than other types of earthworms.

Epigeic earthworms can be raised at several levels of production, from backyard bins to large-scale composting of agricultural, municipal and industrial biosolids (Appelhof *et al*., 1996). Epigeic earthworms fragment organic matter and provide microenvironments for the establishment of decomposing microorganisms. During vermicomposting, earthworms prefer mixtures of feed rather than a single type. Therefore, vermicomposting can be utilized to decompose mixtures of agricultural, urban or industrial organic wastes (Masciandaro *et al.*, 2000). Vermicomposts from these wastes promote growth of crops when added to the soil and compare favorably with greenhouse potting mixtures for production of seedlings and flowering plants (Edwards, 1988). There is need, however, to bridge the gap between controlled vermicomposting within the laboratory and the broader field utilization of vermicomposts in organic resource management. This chapter describes the commonly used terminologies and organisms in vermicomposting and includes step-by-step guidelines on establishing a vermicomposting unit suitable for processing agricultural and domestic wastes.

Earthworms used in vermicomposting are not wild animals and must be protected before they perform properly. They are preyed upon by many species of reptiles, birds and mammals. Even some earthworms are carnivorous, feeding on other, smaller earthworms (Lavelle, 1983). Ants are particularly effective predators of earthworms. Vermicompost containers should be constructed with a concrete base or raised be raised above the ground and covered. The technologies available for proper vermicomposting include beds, windrows and container systems, and each system has a different design.

Containers and box systems are more labour-intensive since batches have to be moved in order to add more wastes or water. It is however, the best technology for backyard vermicomposting of garden and kitchen wastes (Figure 1).

Low cost beds or windrows are the simplest technologies commonly used in vermicomposting. The bed size may vary but it must be freely drained and covered. The cover is only removed when water or new feed is added. The production of vermicompost requires from three to six months.

Figure 1. Raised wooden boxes for vermicomposting, open (left) and closed (right).

Techniques and Terminologies

Vermicompost. A humic substance produced through an accelerated composting process that, when applied to soil, results in improved chemical, physical and biological properties and better conditions for plant growth.

Vermicomposting. This is the use of earthworms to transform organic materials into rich, organic fertilizers. The growth of earthworms in organic wastes is termed *vermiculture* while the processing of wastes using earthworms is known as *vermicomposting* or *vermin-stabilization.*

Casts. Earthworm excreta that constitute the vermicompost (Figure 2).

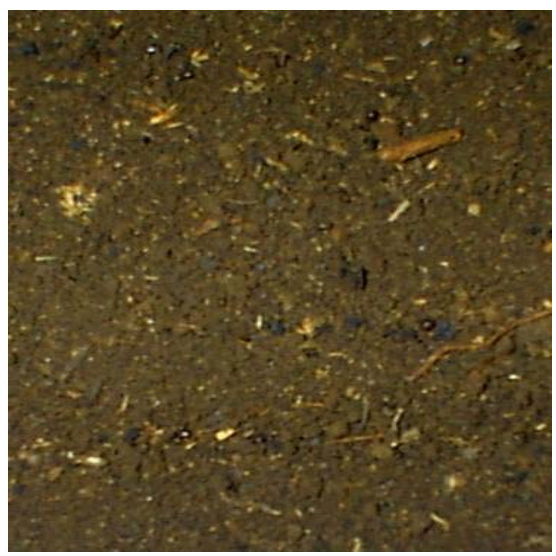

Figure 2. Well cured vermicompost that is ready for use in potting mixtures or horticultural crop production.

Box 1. Differences between composting and vermicomposting technologies

Composting	*Vermicomposting*
Microorganisms decompose substrate	Microorganisms and earthworms combine their activities to transform the substrate
Takes a longer period to mature	Matures relatively faster than compost
Thermophilic stage must be attained	No thermophilic stage is required
Compost is coarser textured	Vermicomposts are finer textured
Risk of heavy metals in the compost	Heavy metals are removed and accumulated within worm bodies

Advantages of Vermicomposting

Vermicomposting is important in both smallhold and large scale agricultural production in several ways. Some of the reasons why farmers will choose to practice vermicomposting are summarized as follows:

- Vermicomposting is rapid and minimizes nutrient losses.
- Suitable earthworms are found throughout the world and the best worms are available through commercial channels.
- Suitable mixtures of organic feeds are widely available and the environmental range for vermicomposting is broad.
- Environmental conditions that affect the survival and distribution of earthworms, moisture, temperature, pH and aeration can be controlled within the vermicomposting bed.
- Vermicomposting processes organic material more rapidly than traditional composting yet the final products are very similar (Box 1).
- Farmers, especially smallhold farmers need inputs for crop production and vermicomosting offers an affordable source of organic fertilizer.

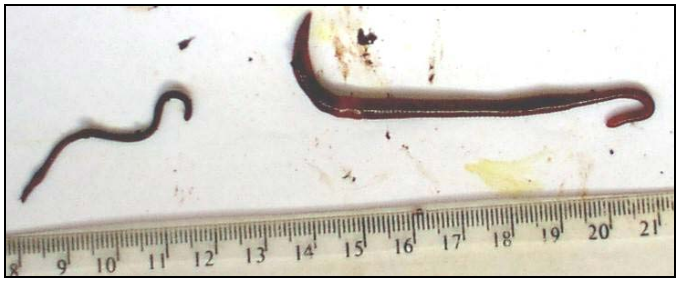

Figure 3. Earthworm species that are well-suited for vermicomposting of agricultural wastes: Kenyan pigmented worm (left) and tiger worm (right).

Vermicomposting Species

The tiger worm *(Eisenia foetida*). This is the most commonly used species in commercial vermiculture and waste reduction (Haimi and Huhta, 1990). The species colonizes many organic wastes and is active in a wide temperature and moisture ranges (Figure 3, right). The worms are tough, readily handled, and survive in mixed species cultures. It is closely related to *Eisenia andrii*, another useful vermicomposting species. The species is commonly used in the U.S., Europe and Australia under the name *Lumbricus rubellus.* This species is raised in Kenya by several flower farms in the Central Highlands and Rift Valley.

Kenyan highland forest pigmented earthworm. A not yet identified earthworm was recovered by the author from highland forest litter near Muguga, Kenya. This species performance is comparable to the well-known *Eisenia foetida* (Savala, 2003). It produces finer vermicomposts than *E. foetida* but the chemical composition is comparable (Figure 3, left).

African night crawler (*Eudrilus eugeniae*). This is a large prolific African worm that is cultured in the U.S. and elsewhere. When large worms are produced under optimum conditions, they are ideal for use as fish bait and in protein processing. It is somewhat difficult to raise because of its intolerance to low temperature and handling. The use of *E. eugeniae* in outdoor vermiculture is limited to tropical and sub-tropical regions because it prefers warmer temperatures and cannot tolerate extended periods below 16^0C (Viljoen and Reinecke, 1992).

Perionyx excavatus. This is a species well adapted to vermicomposting in the tropics. The earthworm is extremely prolific and easy to handle and harvest but it cannot tolerate temperatures below 5^0C, making it more suited to the tropics.

Dendrobaena venata. A large worm with potential to be used in vermiculture and that can also inhabit soils. It has a slow growth rate (Edwards, 1988) and the least suitable species for rapid organic matter breakdown.

Polypheretima elongata. The species is suited for use in reduction of organic solids, municipal and slaughterhouse waste, human waste and poultry and dairy manure but it is not widely available. It is restricted to tropical regions, and may not survive temperate winters.

Production of Vermicompost Using the Bed Technique

Step 1. Construct the bed. Prepare a bed with a concrete, wood or plastic sheet bottom and construct walls 20 to 30 cm in height using wood, logs or stone. Place a wooden board across the bottom and line with chicken wire for better handling and aeration (Figure 4).

Figure 4. A vermicomposting bed with rock walls and concrete floor (Step 1).

Step 2. Add coarse material. Place a 10 to 15 cm layer of coarse organic materials such as banana trash, maize stover, coffee husks and other crop residues on top of the chicken wire (Figure 5). The material must not contain poultry manure as the uric acid is harmful to worms. Composted poultry manure is, however, suitable as feed.

Figure 5. Many coarse-textured materials placed on the floor bed are suitable for vermicomposting (Step 2).

Step 3. Add fine material and water. Place a 5 to 10 cm layer of manure on top of the coarse material. Cattle, pig, sheep or goat manure are suitable. Green manure, such as tree leaves or grass cuttings may be substituted. Mix some of the fine material with the coarse layer. Mixtures of fine materials such as grass cuttings, bean threshing, maize or wheat bran and brewery waste are preferable. If the fine material is available in short supply, then use it to surround specific areas where earthworms are released. Moisten the organic materials prior to the introduction of the worms. Sufficient water should

Figure 6. Clusters of earthworms are introduced into a well-watered composting bed (Step 4).

be applied so that no pockets of dried material remain. Wet materials such as banana trash and fresh manure need little watering while dried materials may require as much as 30 liters of water per m^2 of bed.

Step 4. Release worms. Release the earthworms into the moist bed. Avoid handling individual worms, rather place small handfuls of material rich in earthworms (clusters) into "holes" spaced about 0.5 m apart (Figure 6).

Step 5. Cover the bed. Cover the bed with banana leaves (Figure 7) or dark polythene plastic. Inspect the bed regularly during composting for moisture and

Figure 7. Fresh banana leaves used to cover the bed. Epigeic earthworms avoid light so beds should be covered (Step 5).

the presence of predators. Ants will usually leave the bed if the underlying chicken wire is violently and repeatedly shaken. Add new layers of banana leaves occasionally as the worms consume older leaves.

Step 6. Feed the bed. Organic materials may be applied to the bed regularly as additional layers or in discrete locations. A common practice is to periodically apply additional organic wastes by burying them in different positions within the bed. Vermicompost is ready after three to six months. Additional feeding prolongs the vermicomposting process but yields larger amounts of vermicompost. Withhold feed about three weeks before the vermicompost is collected to obtain a finer and more homogeneous and finished product.

Step 7. Recover worms and vermicompost. When the vermicompost is ready, worms are harvested and compost processed. Place a fine feed material on the bed prior to vermicompost harvesting to facilitate the collection of worms from subsequent “batches”. Wheat bran, brewers’ waste or fresh cattle manure are particularly good feeds that lure earthworms Collected worms may also be fed to fish and poultry. Spread vermicompost in the sun to collect other pockets of worms by hand as the vermicompost dries.

Once worms are collected, the vermicomposting cycle may be repeated. The finished vermicompost is uniform, dark and fine textured. It is best used as the main ingredient in a seedling or potting medium after passing it through a 5 or 10

Figure 8. Collecting earthworms that aggregate within the drying vermicompost for use as feed, bait or starter for the next batch of compost (Step 7).

mm mesh. A typical nutrient content from a manure-based vermicompost using *E. foetida* is 1.9% N, 0.3% P and 2.7% K.

Conclusion

Earthworms are useful in organic waste recycling. If a large number of adult worms (200 to 300) are introduced into one square meter of a 20 cm-deep compost substrate, covered with fine material and optimum conditions provided, mature vermicompost can be produced within as little as 60 days. Vermicomposts have excellent chemical and physical properties that compare favorably to traditional composts. Furthermore, the diversity among epigeic earthworms enables them to be utilized across a wide range of environments and in processing many different organic materials. Earthworms transform wastes into valuable products and a clever resource manager can discover many advantages through this process.

Vermicomposts are best applied to higher-value crops as a source of plant nutrients. The material is also excellent as a major ingredient of potting mixtures and to raise seedlings for transplanting. After vermicomposting, the worms may also be recovered for use as fishing bait or feed for poultry and fish. Earthworms provide an excellent source of protein that could even be consumed by humans but current food preferences tend to discourage this practice. *Worm burger anyone?*

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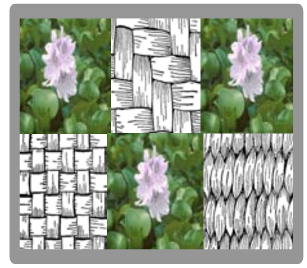
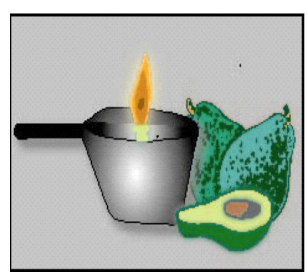


Part 3

Products and Value-Added Processing



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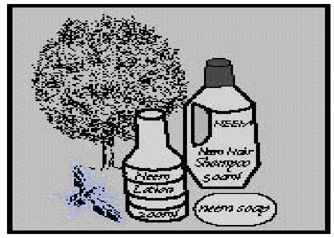

Chapter 12

Production and Use of Products from the Neem Tree

Dorian M. Rocco

The neem tree (*Azadiracta indica*) is a medium-sized tree from Southern Asia belonging to the family *Meliacea.* It has glossy, dark green, compact foliage and aromatic, compound leaves with toothed, curved, pointed leaflets. The flowers are small and cream-white forming thin-skinned yellow berries. The bark is pale grey-brown and grooved. For over 5000 years, the neem tree has been used in India as traditional medicine.

Figure 1. A young neem tree

In East and Southern Africa, neem was widely planted by Indian settlers at the end of the nineteenth century and became naturalized along the coastal strip from Mogadishu to Maputo. Neem was brought to Africa by Asian traders over two centuries ago. Research on the neem tree and its properties has been conducted over the past 40 years, following the observations by Prof. Schmutter of the University of Nairobi (then the Royal Technical College) that a swarm of locusts in the Sudan destroyed all but one tree species, later identified as neem.

By the 1980s, development organizations began to realize the commercial and industrial potential of the tree and its products. In 1995, the International Center of Insect Physiology and Ecology (ICIPE) initiated an awareness programme in East

Africa, and later throughout Africa, to promote the use of the neem tree in agriculture (ICIPE, 1995). Around the same time, a private company, Saroc Ltd. (later renamed Saroneem Biopesticides) started industrial processing and marketing of neem products. In the following years, several entrepreneurs and non-governmental organizations became involved in the processing of neem into soaps and herbal products.

Neem, popularly referred to us the 'health-maker tree', is increasingly in demand because of its many uses in afforestation, animal and human health and as fuelwood and pesticide. Although not indigenous to Africa, it has been planted as an exotic shade tree in many areas for its remarkable properties in controlling insect pests (Figure 1). Whole leaves and seeds may be used or ground into seed oil, seed meal and water-oil emulsions.

Harvest and Oil Extraction

The raw materials used for various neem products are derived from the tree's seeds and leaves. The bark and roots have useful properties as well but their recovery is more destructive to the tree. Collection of seeds along the East African Coast is facilitated by bats that drop the seed after eating the fruit. The fallen seeds should be collected immediately to prevent sprouting and molding. In up-country areas where fruit-eating bats do not occur, it is more difficult to collect seeds but some birds will also drop seeds after eating the fruit. The collected seeds are cleaned and dried, packaged and sold directly to processors or farmers for seedlings. Neem is also valued for wood carving, so leaf and seed recovery may be performed in conjunction with wood harvest. Neem oil is extracted through the following procedure.

1. Small-scale processors will crush seeds using a mortar and pestle. The crushed seeds are placed in a bowl of water. Then the floating oil is skimmed off the bowl
2. A simple hand operated press can extract seed oil leaving a cake. The efficiency of the presser is improved by adding a modified groundnut decorticator. The oil presser can crush 100 kg of raw seeds per day with an oil yield of up to 20%
3. Electrical and diesel machines for crushing the seeds and extracting oil are available although they are costly to buy and maintain. The electrical machine is more efficient in grounding the seeds and uses air pressure to separate kernels from seeds. This method produces clean seeds used for processing higher value products such as medicines.

Neem Products and their Uses

From the process of crushing neem seed for oil, kernel dust and neem cake are also obtained and used to prepare various pesticides and medicines. The cake may be ground into a powder and used as an insecticide. The powder can also be placed in water for 12 hours, resulting in an aromatic solution that is sprayed in the houses to repel various biting and blood-sucking insects.

A variety of commercial products, including pesticides, human and animal medicines and health care materials are produced from the neem seed and are currently being marketed in Kenya.

Figure 2. Mature and ripe neem fruits. The fruit is 1.5 to 2.2 cm in length.

Soap. Neem oil may be converted into soap by mixing with coconut or palm oil then heating and mixing with potash. Potash is obtained by passing water several times through a wood ash, until it has reached the required alkalinity to react with the oils. This soap is then placed in wooden or plastic containers until it hardens sufficiently to be removed.

Insecticides. An alcohol extract of neem seed cake and neem oil emulsifiable concentrate derived from the neem seed are used for the control of many insect pests and fungal diseases. The seed powder made from neem seed cake is recommended for controlling crawling insects. Neem oil is also used as an insect repellant.

Alcohol may be passed through the cake to produce an alcoholic extract which contains oil residues and a large number of terpenids, in particular azadiractin, a compound that is contained in the oil in very small proportions. By passing the alcohol extract through several lots of cake, the azadiractin content can be increased resulting in a material with exceptional insecticidal properties.

Medicine. Three products are derived from the neem seed for the treatment of human diseases. These products are neem leaf powder, neem oil and neem soap. Neem leaf powder is recommended for respiratory diseases, diabetes, typhoid, amoeba, malaria, hepatitis, fatigue, pneumonia, and eye and kidney infections. Refined neem oil derived through filtration is recommended for treatment of skin rashes, pimples, dandruff, wounds, scalds, worms and fungal infections. It is also used as an anti-bacterial medicine to treat teeth and gum problems. A third product is neem soap, which is useful against fungal skin infections, ringworm and athletes' foot, and as an insect repellent against lice, fleas, ticks and mosquitoes. Skin problems treated with neem oil include acne, itching, dandruff and allergies. It was also used to treat chicken pox, wounds, scalds and burns. Twigs are cut to make tooth brushes to prevent tooth decay. Leaves are boiled for use against malaria, diabetes, stomach problems and asthma. Leaves should be dried and ground into neem powder before boiling.

Figure 3. Some of the medicated neem tree products that are used as cosmetics.

Veterinary medicine. Neem powder derived from both the seed and the leaf is used to treat animal diseases such eye infections, coccidiosis and Newcastle disease in poultry. It is also used as a vermifuge in domestic animal husbandry. The wood and bark of the neem tree is processed into neem cake and it is fed to livestock as a deworming medicine.

Organic fertilizer. Neem cake and neem shells are combined to form neem fertilizer that is applied as an organic amendment to soils and plant growth stimulant.

Conclusion

Neem tree products contribute to human and animal health, plant nutrition and growth, and environmental conservation. Through these functions, the neem tree products have a great potential for income generation. Nonetheless, there is need to further promote awareness of the neem tree, its uses and products. Integration of socioeconomic studies into biological research will greatly enhance the potential of this tree and its utilization. Information materials such as publications, booklets, flyers, audiovisual tutorial modules and documentary films should be prepared, distributed and disseminated through national extension channels in various African countries.

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Editors Note. The editors are not medical professionals and as such cannot verify the medical claims in this chapter. We do note, however, that several neem-based healthcare products are marketed throughout the world, including Kenya. We remind readers that they should not attempt to treat persistent symptoms or serious medical conditions without the advice of a doctor.

Figure 4. Packaged neem oil (left) and cake (right).

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Chapter 13

Preparation and Use of Gum Arabic and Its Products

Joseph K. Mwangi and Francis M. Mwaura

Gum arabic is a natural gum that is obtained from *Acacia senegal* and *A. seyal*, two leguminous trees originating from Africa. Acacias are one of the most common trees in Africa's semi-arid savannas and *A. senegal* occurs throughout the Sahel and Sudanese woodlands, in the Great Rift Valley and into Southern Africa (White, 1983). These trees have compound leaves with small leaflets, small white to cream colored flowers and form thin woody pods. Sudan is the dominant producer of gum arabic, accounting for over 80% of world production, with Chad the world's second largest producer.

Gum arabic is collected from exudates on tree branches that are produced through a process called gummosis, one that serves to seal tree wounds and protect against extreme heat and desiccation (Figure 1). In Kenya, similar material is also harvested from *Acacia meansii* and *Acacia abysinica.* Processed gum arabic has well-established characteristics in terms of solubility, color, emulsification and film formation, and these properties are very important within many commercial and industrial processes.

The quality of the gum is determined by the maturity of the tree with older trees producing better quality gum than younger ones. The colour of the harvested gum is an important consideration in quality assessment. A dry, colourless-to honey-brown tree secrection produces higher quality gum.

The trunk and branches may be cut at several positions to induce greater exudation. The exudates dry within a few days after secretion and are then ready for collection. If the exudates are too wet, it is recommended to air dry them immediately. It is also recommended to harvest the exudates during the dry season as they are better than those processed from exudates harvested in the rainy season. After harvesting, the gum exudates are sorted depending on the intended use of the final processed gum. On average, each tree produces approximately 20 kg of gum per month in Kenya. Other trees such as wattle (*A. mearnsii*), also produce useful gum exudates, but these trees are less productive, yielding only 2 to 3 kg of secretions per month.

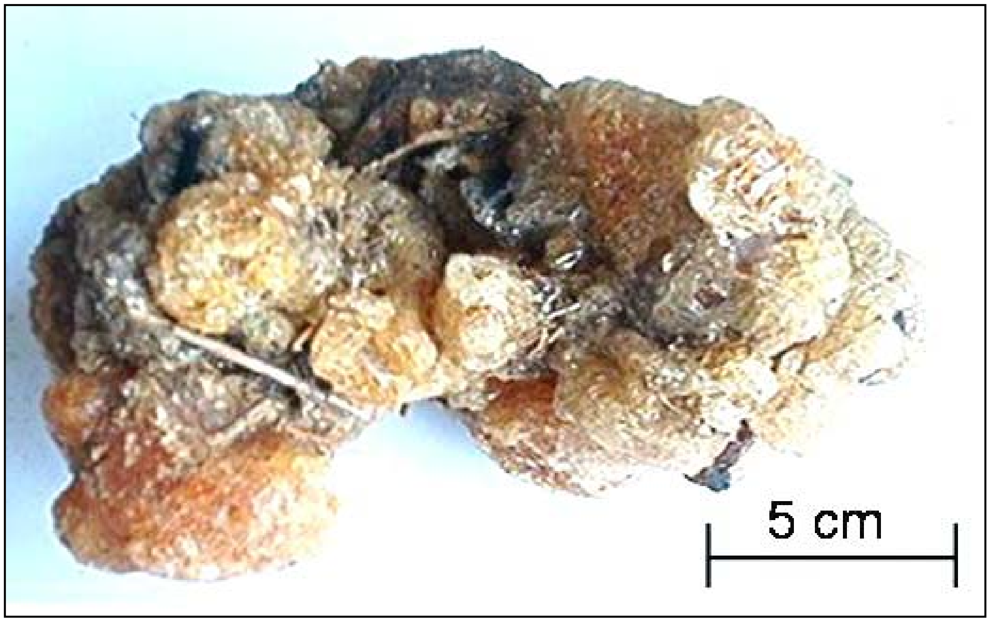

Figure 1. Tree secretions from *Acacia senegal* are collected and processed into commercially-available gum arabic

Processing Gum Arabic

1. Crush the dried clumps of exudates into small pieces of ≤ 2 cm^3.
2. Put the crushed exudates in a container and add a small amount of 'Guar' gum to make the crystals dissolve more evenly. Guar gum can be bought from food processors. The ratio of guar gum to the tree gum exudates depends on the quality of the gum to be made. Higher quality gum arabic requires the addition of less guar.
3. Add water at a ratio of 1 part gum to 10 parts water. For example, 1 kg of crushed gum is added to 10 litres of water. When the gum is completely dissolved, check for expected viscosity to further adjust the ratio of water to gum.
4. Filter the mixture using a clean cloth (Figure 2).
5. If necessary, add a coloring agent. For example, food coloring may be added to give the gum a prefered colour.
6. Package the gum in plastic containers of sizes that meet different customers' requirements in the market.

Figure 2. The author presented an exhibit during the FORMAT 2002 that demonstrated the processing of gum arabic for industrial purposes

Uses of Gum Arabic

Gum arabic is an important material to many industries including confections and baked goods, beverages, encapsulated flavors, pharmaceuticals, cosmetics, printing, textiles and other applications, as well as the preferred "sticker" for seed inoculants in agriculture (Box 1).

Confectionery and baked goods. Gum arabic retards sugar crystallization in gum drops and emulsifies and distributes fat particles in caramel and toffee. In panned sugar confections, it serves as a coating agent and film-former. Gum arabic is a lubricant and binder in extruded snack cereals, at levels from 2-5%. At 15-40% levels, gum arabic provides adhesion of dry flavors in peanuts and similar products. In low-fat cake and muffin mixes, gum arabic functions as a partial oil replacer as well as a moisture binder. Gum arabic's water solubility, low viscosity, and adhesiveness gives it value as a glaze for buns to provide gloss and flexibility and also makes it useful as a component in toppings and icing bases, and in applications where its emulsifying power is important. It can be used to encapsulate baking flavors, such as cinnamon oil, for dispersal in vegetable fats and for use where flavor release is wanted at specific melting temperatures.

Box 1. Favorable characteristics of gum arabic

Multifunctional: good emulsifier, film-former, texturizer and low-viscosity water binder and bulking agent.

High source of fiber: contains no less than 85% soluble dietary fiber

High purity: no additives; free from sediment and impurities; has extremely low bacterial counts

Fast hydration and ease of dispersion: available in prehydrated or agglomerated form.

"Natural" labeling: Gum arabic is not chemically modified and qualifies for claims of "no artificial additives".

Beverages. Gum arabic is a useful and inexpensive hydrocolloid emulsifier, texturizer and film-former that is widely used in the soft drink industry to stabilize flavors and essential oils. The simultaneous presence of hydrophilic carbohydrate and hydrophobic protein in the gum arabic enhances its emulsification and stabilization properties. Emulsification is particularly improved due to molecular flexibility that allows greater surface interaction with oil droplets. Gum arabic is used in confectionery and pastries and as a foam stabilizer in marshmallows. The gum arabic glycoprotein possesses a flexible but compact conformation. It is readily soluble to give relatively low viscous Newtonian solutions even at high concentrations of about 20-30 % (Fennema, 1996).

The effectiveness of gum arabic as an emulsifier has given it broad application in foods. It has an especially strong position in the soft drink industry as a stabilizer of citrus oil emulsion concentrates. It fills an important application in beverages as a cloud-producing agent and dry mixture where a spray-dried emulsion of gum arabic and hydrogenated vegetable oil produces a stable, free-flowing powder that, on dispersal in water, provides a cloudiness or turbidity typical of citrus or other juices. A modified form of this procedure is used in formulation of several dry beverage mixes. The foam-stabilizing ability of gum arabic is used in beer and certain soft drinks to stabilize the foam "lace" on the side of the glass.

Encapsulated flavors. Gum arabic is an ideal carrier in flavor encapsulation because of its natural emulsifying and surface-active properties, good retention of volatile flavor components, high solubility in water (up to 50%) and pH stability. Additional advantages include its neutral flavor, low hygroscopicity and ability to protect flavors from oxidation. For example, acacia gums protect orange oil against oxidation more effectively than does modified starch.

Pharmaceuticals. Supplementation with gum arabic increases feacal nitrogen excretion and lowers serum urea nitrogen concentration in chronic renal failure patients consuming a low-protein diet. A daily dose of 25 g would approximately double the amount of energy available to the colonies of bacteria that inhabit the human digestive tract. These bacteria grow by fermenting dietary fiber, and as they grow they absorb nitrogen. They are also capable of degrading urea to ammonia. They themselves are then excreted in feaces, taking some of the body's nitrogen waste with them.

Only small quantities of gum arabic are used in pharmaceuticals. These uses depend upon its emulsifying, suspending, demulcent or coating characteristics. The gum maintains suspensions when used in rather high concentrations. Owing to its mild ability to complex heavy metal ions, it brings about better suspension of these salts when needed, for example, in the suspension of calamine lotion. It also functions as a binder in cough drops and lozenges.

Cosmetics. Gum arabic stabilizes lotions and protective creams. It increases the viscosity, assists in imparting spreading, adds a smooth feel to the skin, and forms a protective coating. It is also a binding agent in the formulation of compact cakes and rouges, and acts as an adhesive in the preparation of facial masks. A typical compact cake is composed chiefly of a pigment, a mineral oil, and an aqueous solution of gum arabic. The gum is also used as a foam stabilizer in liquid soap. Gum arabic has been recommended for use as a fixative and binder in hair creams and as a stabilizer and film former in protective creams.

Printing and textiles. Since the nineteenth century, gum arabic has been combined with a sensitizer and a soluble pigment, applied to paper, and exposed through a negative under a powerful light source. This can produce beautiful prints only surpassed by adding further layers of gum pigments in registration. It is also possible to print color separated black-white negatives to produce true color prints, but precise registration is required.

In the past, gum arabic was extensively used in the aluminium plate printing process. Normally after printing, the plate would be cleaned with chemicals and covered by a gum arabic solution before re-using the plate. The process works by sensitizing a part of the printing plate so that it will accept grease, oil and printing ink. An image is drawn or transferred on to an aluminum or zinc plate and 'etched' with a solution of gum arabic, water, and nitric acid. Offset lithography continues to be an important printing process because of its low costs for film preparation and press operation, although the advent of digital processing has reduced its importance somewhat.

Gum arabic is used to make the yarn stronger and increase its tensile strength. Many textile manufacturers use modified starch mixed with gum arabic. Gum arabic can also be added to the painting formula to fix the pigment in the fabric, thus saving fabric printing costs.

Other industrial and household applications. The essential ingredients in watercolors are pigments, a binding agent (usually gum arabic), and water. When combined these three components create transparent watercolor. Pigments are ground and a liquid gum arabic solution is added to produce paint that is more opaque and which imparts a dusty quality to the surface. Gum arabic is resoluble even after drying, therefore it can be stored as dehydrated cakes. Occasionally oxgall (a wetting agent) is added to water color to aid dispersion of the pigment.

Industrial moulds must be covered with lubricant prior to injection to make the moulded material easier to extract, but paraffin wax alone is too difficult to remove. Alternatively, manufacturers may mix gum arabic with the paraffin and then place the mold into hot water, allowing the gum arabic to dissolve and remove the accompanying wax.

Ink may be prepared using gum arabic as follows. Collect "lamp black" the soot resulting from burning and slowly add water to produce an inky black solution. Then, add a small amount of gum arabic solution to thicken the ink for writing. For a longer shelf life, store the ink in an air-tight container. A basic permanent ink can be prepared by mixing 1 egg yolk, 1 teaspoon full gum arabic and 1 cup honey in a small bowl. Add 1 teaspoon lamp black to make a thick paste and store in jar.

Powdered gum arabic is a simple adhesive for paper products and may be used directly after dissolution in two or three times its weight in water. A 40% aqueous solution has been made as mucilage for general office purposes. Gum arabic solutions are also excellent adhesives for "sticking" inoculants of beneficial bacteria onto legume seeds (Lowther *et al*., 1989).

Conclusion

The price of gum arabic varies with its grade and intended use, with the purest gum arabic used in pharmaceuticals (KSh 400 per kg) and food processing (KSh 200 per kg). Industrial grade gum arabic markets for KSh. 80 to 100 per kg. Gum arabic has "untapped" potential to stimulate income generation and industrial activities, however, the supply of the raw material must be sustained through protection of existing stands and additional tree planting of selected *Acacia* spp. Training of traders and collectors in gum collection and storage will improve the quality of the final products. Acacia trees and gum arabic are important organic resources in Africa and should be considered by planning and development agencies as an important component for rural transformation in semi-arid areas.

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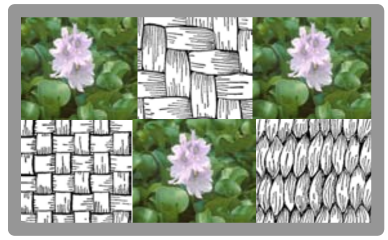

Chapter 14

Handicrafts Prepared from Water Hyacinth

Millicent A. Olal

Water hyacinth (*Eichhornia crassipes*) is a floating aquatic plant that varies in size from 8 cm to more than one meter in height. It has showy lavender flowers and leaves that are rounded and leathery, attached to spongy and sometimes inflated stalks. The plant has dark feathery roots. Fresh waters of East Africa are among the last areas to be infested with water hyacinth (Amoding *et al*., 1999), a noxious aquatic weed that has become difficult to control (Woomer, 1997). One consequence of water hyacinth invasion is restricted access to aquatic resources, however, this weed may be used to make handicrafts that provide an important source of income for the affected communities (Lindsey and Hirt, 2000).

Figure 1. A Takawiri love seat woven by artisans from Hyacinth Crafts (author seated).

Sensing a business opportunity in 1998, Hyacinth Crafts, with assistance by the Kisumu Innovation Centre Kenya, developed several handicraft products from water hyacinth fibre (Figure 1). Currently more than 35 families engage in the collection of water hyacinth and preparation of fibre. This fibre is delivered to 30 weavers and 20 papermakers, who produce an assortment of furniture, household accessories, office supplies, stationery and gift items. These products are then marketed in Nairobi and other major towns in Kenya. The production of fiber

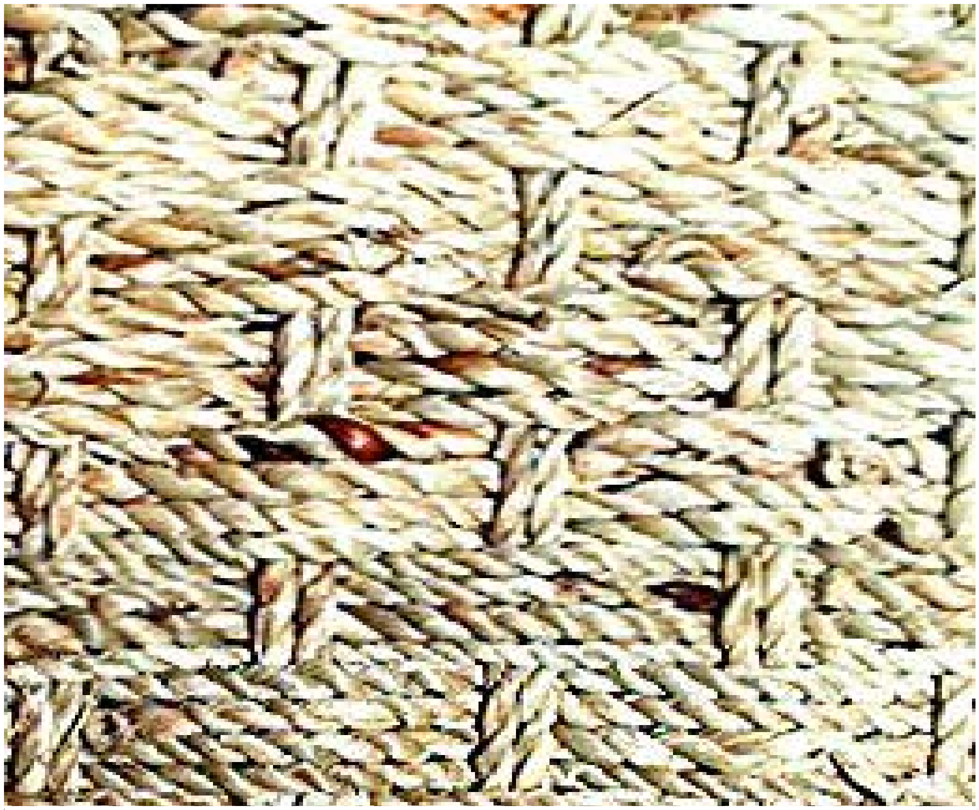

Figure 2. One of the possible weaving patterns using twisted water hyacinth rope.

products by cottage industry artisans in areas most severely affected by water hyacinth empowers those who would otherwise suffer hardships from reduced access to fishing grounds. In this way, Hyacinth Crafts "*turns gloom to bloom and doom to boom*", as was stated in a recent article describing the enterprise's operations (Olal *et al*., 2001). Furniture and household accessories processed from hyacinth fibre include lampshades, napkin holders, breadbaskets, picnic baskets, place mats and floor mats. Office articles include diverse items such as waste bins, file holders, stack trays, pen holders and desk organizers.

Many other products can be processed from water hyacinth (Thyagarajan, 1984). Swine, ducks and geese readily consume fresh hyacinth stems and leaves. A protein concentrate that is also rich in vitamin A may be prepared from the leaves. The dried plants are a suitable substrate for mushroom cultivation. Wastes removed from freshwater may be processed into silage for livestock or compost for addition to soil (Woomer *et al*., 1999). Biogas may be generated through anaerobic digestion and fuel briquettes may be compacted from dried, shredded stems. In addition, the dried roots serve as a major component of potting

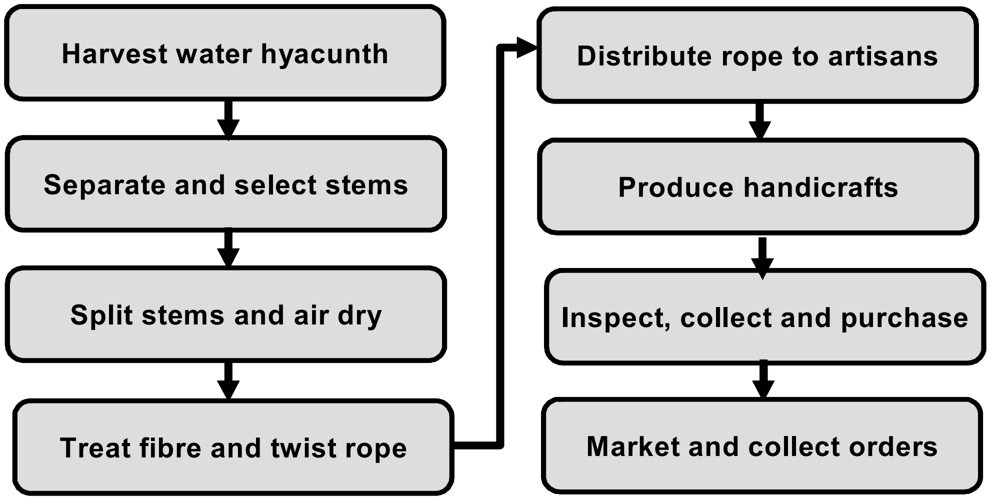

Figure 3. The processing of water hyacinth fiber and the subsequent production and marketing of handicrafts by Hyacinth Crafts.

mixtures. Nonetheless, the production of woven handicrafts made from water hyacinth appears to have a competitive advantage among other options for utilization of water hyacinth in East Africa (Lindsey and Hirt, 2000).

Processing Water Hyacinth into Fibre

Many different handicrafts are prepared from twisted or braided fibre (Figure 2). To produce this fibre, the following procedure is followed.

1. **Recover.** Fresh water hyacinth is recovered and the leaves and roots removed. The stem should be at least 50 cm long and mature, as young stems produce brittle or soft fibre.
2. **Split.** The stem is then split lengthwise. The number of pieces prepared from a single stem is determined by the thickness of string required, but each slice should be at least 2.5 cm in cross-section. The pith, soft plant tissue that surrounds the hollow stem, is removed by rubbing after one day of sun drying. Do not dry the strands for more than three days or they will become brittle.
3. **Dry and dye.** The cut, split stems are air-dried for 4 to 6 more hours in the direct sun until stems are dry but pliable. Further drying is necessary if only colored ropes are required.
4. **Treat and sort.** Treat dried stems with a preservative to control fungal decay. Prepare 250 g of sodium meta-bisulphite in 10 liters of water. Soak 5 kg of stems by submerging for 1 hour. Rinse the stems in room-temperature water and air dry for 1 day. Sort stems by length and cross-section so that rope and braid is more uniform.

5. **Twist or braid.** Fibre may be either twisted or braided into ropes of different thickness depending on the crafts to be made. Before braiding, sort the strips into various lengths and thickness. For rope, twist two pieces of stem fibre into one by rolling. For braid, pass three pieces over-and-through to produce a single braided length.
6. **Join.** Toward the end of each stem segment, the fibre tapers. Combine additional tapered ends by joining additional twisted or braided segments until the desired length is achieved. As the fibre is processed, it is rolled into loops or spools. Hyacinth Crafts purchases the rope or braid from lakeshore producers and then distributes it to local artisans, who weave it around metal or wooden frames to make handicrafts. The process of collecting water hyacinth stems and processing fiber, and subsequent production and marketing activities of Hyacinth Crafts are presented in Figure 3.

Processing Water Hyacinth into Paper

Water hyacinth fiber is suitable for the production of many different grades of paper from cardboard and construction paper to blotter and near-bond, although the higher grades require the addition of rag or waste pulp. Pulping the water hyacinth fibre is facilitated by the addition of sodium hydroxide or lime (0.5%). As the fibre is rather dark, bleaching is required to produce lighter colored paper, or those intended for dying. A simplified procedure for the production of craft paper follows, and those interested in producing other grades are referred to Lindsey and Hirt (2000).

1. **Recover and dry.** Recover hyacinth plants with stems at least 30 cm long, discard roots and leaves and air dry until nearly crispy.
2. **Chop and shred.** Chop 1 kg of dried stems into small pieces and shred them with a mill or mortar and pestle. For finer grade paper, also shred 1 kg of waste white paper.
3. **Pulp.** Combine 2 kg of shredded fibre to 1.5 liter of hot water and boil for several hours, mashing occasionally. One (1.0) g sodium hydroxide (soda) or calcium hydroxide (lime) may be added at this point, but may be unnecessary if waste paper is added to the pulp. Wear gloves and protective eyeglasses when handling soda, lime or bleach, and the unwashed pulp.
4. **Wash and bleach.** Drain the excess moisture by squeezing the pulp over a strainer and return to a pot, add sufficient water to cover the pulp, add 50 ml of bleach (calcium hypochlorite 65% solution), stir and stand for 30 minutes. Return the bleached fibre to the strainer, drain and rinse with water until no smell of the bleach remains. Dyes may be added at this time.
5. **Spread, lift and dry.** Spread a thin layer of the pulp over fine cloth and a lifting net, drain excess water and press the sheet. Lift the sheet from the press using the lifting net and dry for several hours.
6. **Trim.** Cut the paper to specified dimensions and stack into reams.

A simpler alternative method of plant preparation and pulping follows:
1. **Collect.** Collect the whole water hyacinth plant and discard the roots
2. **Rot.** Pile the stems and leaves and allow them to rot for several days
3. **Rinse.** Recover and rinse the decomposing material, which now consists of mostly fibers
4. **Pulp.** Pulp the material in a large mortar and pestle
5. **Continue.** Wash, spread and trim as described in steps 4 to 6 (above).

This approach results in a darker, coarser-textured craft paper that is well suited to card-making and scrapbooks.

Conclusion

One way to be innovative in resource management is to turn apparent disadvantage into opportunity. The production of fibre products by cottage industries is one such example. Utilization of water hyacinth for the production of handicrafts is an important way of managing the weed problem in the fresh waters of East Africa because it creates employment and generates income for those who are most affected by it. Everyone wins when we turn this terrible weed into organic fertilizer, livestock feed or furniture except when we unintentionally transport the weed to new waters (Woomer, 1997). For example, those transporting the weed prior to processing must be aware of the plant's abundant, small seeds and take care that they are not introduced to new areas. Even finished compost or silage may contain viable seeds! Better safe than sorry as far as the spread of water hyacinth is concerned.

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Edited by C.E.N. Savala, M.N. Omare
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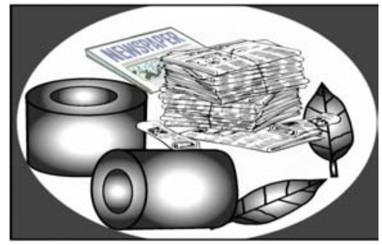

Chapter 15

Recycling Waste into Fuel Briquettes

Jacob K. Kibwage, Simon N. Munywe, Jonathan Mutonyi, Canon N. Savala and E. Wanyonyi

The use of organic waste as cooking fuel in both rural and urban areas is not new. In seventeenth-century England, the rural poor often burned dried cowdung because of the acute shortage of wood fuel due to widespread deforestation (Lardinois and Klundert, 1993). In some Asian and African countries, cattle and buffalo dung is still used as relatively good cooking fuel. In the beginning of the nineteenth century, sawdust briquettes were made with binding materials such as tar, resins and clay bind the small particles together. None of these processes attained great importance because of their relatively high costs compared to wood and conventional charcoal fuels (Lardinois and Klundert, 1993).

Fuel briquettes emerged as a significant business enterprise in the 20th century (Figure 1). In the 1950s, several economic methods were developed to make briquettes without a binder. A multitude of factories throughout the world produced literally tens of millions of tons of usable and economic material that met the household and industrial energy needs. During the two World Wars, households in many European countries made their own briquettes from soaked waste paper and other combustible domestic waste using simple lever-operated presses (Lardinois and Klundert, 1993). Today's industrial briquetting machines, although much larger and more complex, operate on the same principle although the marketed briquettes are now sold at a premium for occasional backyard barbeques rather than for everyday use.

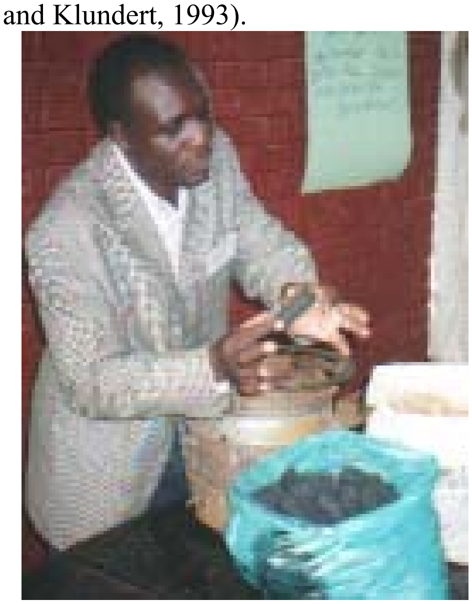

Figure 1. Mr. Mutonyi displays briquettes made from sugar bagasse during a past FORMAT event.

For over 100 years informal waste collectors in Cairo have separated and dried organic waste products for sale as fuel for domestic use. This process faded somewhat when fossil fuel sources became available. Switching to conventional fuels may prove advantageous to those who can afford them, but given the economic and energy conditions in many cities, urban and agricultural wastes remain a viable alternative fuel.

Briquetting is undergoing resurgence, principally due to the convergence of three critical factors. First, the recent developments in briquette processing and binding have dramatically changed the economics of using fuel briquettes as an energy resource. Secondly, a shortage of fuelwood has become increasingly severe in most of the developing countries. Finally, there has been a steady increase by environmental concerns to address the problem of domestic and urban waste disposal, a dilemma that briquetting can help remedy. This chapter explores the opportunity of using sugar bagasse, sawdust and urban waste as cooking fuel in Kenya and provides step-by-step guidelines on making briquettes.

Making Fuel Briquettes

Briquetting involves the collection of combustible materials that are not usable as such because of their low density, and compressing them into a solid fuel product of any convenient shape that can be burned like wood or charcoal (Figure 2). Thus, the material is compressed to form a product of higher bulk density, lower moisture content, and uniform size, shape and material properties. Briquettes are easier to package and store, cheaper to transport, more convenient to use, and their burning characteristics are better than those of the original organic waste material.

The raw material of a briquette must bind during compression; otherwise, when the briquette is removed from the mould, it will crumble. Improved cohesion can be obtained with a binder but also without, since under high temperature and pressure, some materials such as wood bind naturally. A binder must not cause smoke or gummy deposits, while the creation of excess dust must also be avoided. Two different sorts of binders may be employed. Combustible binders are prepared

Figure 2. A demonstration on burning characteristics of fuel briquettes during a past FORMAT event

Table 1: Cane milled and bagasse statistics at Nzoia Sugar Factory (after Keya, 2000)

Year	Harvested Area (ha)	Fibre % Cane	Cane Milled	Estimated Bagasse	Est. Used Bagasse	Excess Bagasse
			-----------------------------	---------ton---------	-----------------------------	
1995	6134.7	17.6	424427.3	74571.9	51805.6	22766.3
1996	3747.2	18.3	306438.7	56078.3	39640.9	16437.4
1997	5579.6	18.3	453618.5	82966.8	58634.7	24332.1
1998	5697.7	17.7	471135.4	83249.6	57977.9	25271.7
1999	9192.4	17.2	602528.3	103755.4	71435.8	32319.6
2000	6919.1	16.6	320421.4	53157.9	35970.5	17187.4

from natural or synthetic resins, animal manure or treated, dewatered sewage sludge. Non-combustible binders include clay, cement and other adhesive minerals. Although combustible binders are preferable, non-combustible binders may be suitable if used in sufficiently low concentrations. For example, if organic waste is mixed with too much clay, the briquettes will not easily ignite or burn uniformly. Suitable binders include starch (5 to 10%) or molasses (15 to 25%) although their use can prove expensive (Lardinois and Klundert, 1993). It is important to identify additional, inexpensive materials to serve as briquette binders in Kenya and their optimum concentrations. The exact method of preparation depends upon the material being briquetted as illustrated in the following three cases of compressing sugar bagasse, sawdust and urban waste into cooking briquettes.

Fuel briquettes from sugarcane bagasse

Surplus bagasse presents a disposal problem for many sugar factories. For example, at Nzoia Sugar Factory in Western Kenya, the average tonnage of excess bagasse produced per year is over 24000 tons (Table 1). Using a bagasse-to-briquette conversion ratio of 5:1, Nzoia could produce 4845 tons of bagasse charcoal briquettes (Keya *et al*., 2000). The pilot briquetting technology remains simple, applicable and of benefit to surrounding communities, and a low cost product that competes with wood charcoal is now being test marketed.

The production of carbonized bagasse briquettes by Chardust Ltd. based at Chemelil Sugar factory involves the following stages:

1. **Size reduction.** Chop, rolling or hammer fresh sugarcane bagasse
2. **Drying.** Remove moisture in the bagasse by open air drying or by using forced, heated air in a large rotating drum
3. **Carbonization.** Combust the dried bagasse under limited oxygen conditions in a buried pit or trench until it carbonizes into charcoal

4. **Preparation of feedstock**. Mix carbonized bagasse with binder (e.g. clay or molasses) to form the briquette feedstock
5. **Compaction and extrusion**. Pass the material through a machine- or manually-operated extruder to form "rolls" of charcoal.
6. **Dry the rolls.** Air dry the rolls for 1 to 3 days, causing them to break into chunks
7. **Package and market.** Package the briquettes in 2 kg labeled bags and sell for a market price of KSh 30 (US $0.40)

The product is sold under the trade name *CaneCoal*. It is less expensive than regular charcoal and its use conserves diminishing forest resources in Western Kenya. Its marketing strategy is to produce lower-cost briquettes that light quickly and burn longer without producing sparks, smoke or unpleasant odors.

Fuel briquettes from sawdust

Sawdust is waste material from all types of primary and secondary wood processing. Between 10 and 13% of a log is reduced to sawdust in milling operations. Sawdust is bulky, and is therefore expensive to store and transport. Also, the calorific value of sawdust is quite low, so that briquetting is an ideal way to reduce the bulk, to increase the density, and thus to increase the calorific value. The equipment required for producing sawdust briquettes consist of a drier, a press and an extruder with a tapered screw and a large revolving disk.

The sawdust briquettes are formed under sufficiently high pressure to produce cohesion between wood particles. The lignin softens and binds the briquette, so no additional binder is required. The sawdust fuel briquettes are cylindrical, with a diameter of 11.5 cm and length of 30.5 cm. They are packed into 40 kg bags. The advantages of producing sawdust fuel briquettes include:

- The price of sawdust fuel briquettes is about the same as fuel wood but is much more convenient to use as they do not require further cutting and chopping
- They burn very well in any kind of solid fuel stove and boiler
- The ignite quickly and burn cleanly, producing only 1% to 6 % ash
- The briquettes don't contain sulphur and burn without producing odor
- The burning of 1 kg of sawdust fuel briquettes produces 18000 KJ caloric power, roughly equivalent that of medium quality coal
- A briquette plant may be profitably integrated into larger sawmilling operations

Due to present limitations of equipment currently available in Kenya, locally-produced sawdust briquettes have suboptimal densities, causing incomplete burn and excess smoke. Attempts are underway to improve this technology, particularly by adjusting the screw length to diameter ratio, the screw rotation speed, feed pressure, and residence time in the extension chamber as a means of producing a higher-density, better quality briquette.

Figure 3. Two briquetting devices developed in Kenya that were displayed at a FORMAT event by the Millennium Fuel Project (left) and the Kayole Environmental Management Association (right).

Fuel briquettes from urban waste

Solid waste disposal is one of the most serious urban environmental problems in developing countries. In Kenya, municipal authorities collect and dispose less than 40% of these wastes. This failure is attributed to inadequate resource mobilisation, over-reliance on imported equipment, use of inappropriate technology, lack of public awareness on waste management, absence of sufficient capacity for waste processing and recycling, and non-implementation of environmental laws pertaining to waste disposal (Kibwage, 2002). Open or crude dumping is the most common method used by municipal authorities. Waste poses a health hazard when it lies scattered in the streets and at the dumping sites. It is now an accepted environmental philosophy that wastes have value and should be utilized based on the four "R"s "Reduce, Reuse, Recover and Recycle". Through recycling, urban wastes are transformed into useful products. Waste paper and leaves, in particular, provide a potentially important, alternative source of cooking fuel.

Waste paper and leaves are molded into cylindrically-shaped products using simple hand operated equipment (Figure 3). Conversion of organic wastes into cylindrical fuel briquettes is being undertaken by several NGOs and CBOs in the country. Both at Nairobi's Millennium Fuel Project and the Kayole Environmental Management Association (KEMA), briquette making is a priority activity because of the profits involved. The briquettes represent an alternative source of cooking

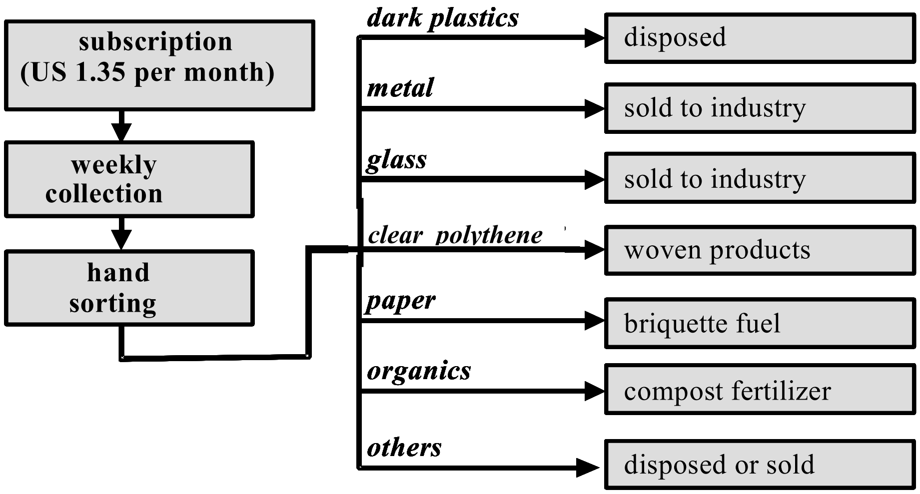

Figure 4. Activities undertaken by KEMA during its waste management work

energy and a viable opportunity for income generation, while at the same time contribute to environmental preservation. The Kayole Environmental Management Association has employed street boys to collect garbage from the residents of Kayole Estate within Nairobi City. Garbage is also collected from the streets and dumping grounds. Collected garbage is sorted and non-useful materials are disposed (Figure 4). Selected useful materials are either sold directly to waste recycling industries or used by the association to produce woven handicrafts, compost and fuel briquettes.

KEMA has developed an innovative screw-operated device that compacts organic wastes into cooking briquettes (Figure 3). Wastes must be sorted prior to the briquetting process by removing all metals, plastics, and other non-combustible materials, reducing their moisture content to at least 20% and chopping courser feedstock into pieces 1.0 to 2.0 cm or less.

Figure 5. A simple electrical powered briquetting machine.

To make 100 briquettes, follow these seven steps:

1. Collect waste paper, cartons and dry leaves (about 10 kg when dry)
2. Soak these materials in water for 3 hours
3. Add charcoal powder (about 0.5 kg) to colour the briquettes (optional)
4. Pulverize the materials into mash using a large mortar and pestle
5. Place mash into the compression cylinder of the briquette maker
6. Compress and drain the mash
7. Remove the briquette and dry for two or three days

Three dried briquettes will burn for at least 3 hours and are sufficient to prepare tea and a traditional Kenyan meal such as *githeri* (a mixture of potatoes, maize and beans).

Conclusion

Recycling of organic materials into fuel briquettes contributes to solving urban needs such as income-generation, insufficient land for waste disposal and maintaining environmental quality. Since the earth's resources are finite, greater resource recovery and utilization are essential to achieve an acceptable level of organic waste management. Enhancing the recovery of organic waste can restore various natural cycles, thus preventing the loss of raw materials, energy and nutrients. On the other hand, the demand for energy in Kenya is expected to add to the emission of greenhouse gas through burning of fossil fuels. There is urgent need to promote climate-friendly technologies in Kenya and other developing countries in Africa and fuel briquetting appears to be one such technology that addresses the multiple needs of society and the environment. Current research addresses is focused upon finding better binders for bagasse briquettes, improved calorific values and combustion by producing higher density briquettes, introducing more efficient extrusion methods (Figure 5) and reducing production costs. When the market price of briquettes is less than that of wood charcoal and a regular supply of briquettes is assured, then many new market and environmental opportunities emerge.

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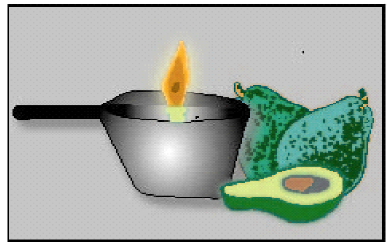

Chapter 16

Preparation and Use of Avocado Oil and Its Products

Julius K. Muigai and Francis M. Mwaura

The Avocado (*Persea americana*) belongs to the family Lauraceae, a family of mainly tropical trees and shrubs. Other well-known members are laurel, cinnamon, sassafras and greenheart (Samson, 1986). Avocado is native to tropical America. It is a shallow-rooted evergreen tree that grows up to 20 m tall. Its leaves are simple, ovate and spirally arranged. The white flowers are borne in clusters on auxiliary panicles. The avocado fruit is generally pear-shaped with a large, round to egg-shaped central seed. The flesh is buttery in texture, contains a high percentage of oil and protein and has a high calorific value (Rice *et al*., 1986). Avocado is common throughout the tropics and subtropics (Martin *et al.,* 1987).

Avocado trees perform well in areas with warm, frost-free climates. The flowers are sensitive to low temperatures and frost during blooming results in substantial crop loss. Optimum growth occurs in fertile, well-drained soils, although they are tolerant to a wide range of soil types except those with excessive salinity (Koch, 1983). The trees respond well to fertilizers especially phosphorus in the early stages of growth, and to nitrogen and potassium in the later growth stages. Soil pH levels and root disease conditions affect the tree's ability to absorb nutrients. Avocado has a number of pests and diseases but the most serious is *Phytopthora cinnamomi* which causes root rot, seedling blight and stem canker (Gachanga and Ilg, 1990). For better crop establishment, farmers are encouraged to use disease or pest prevention that includes treatment of rootstock before planting, use of root-rot resistant grafting stock, and planting on ridges in deep, well drained soils.

Three different subspecies, Mexican, Guatamala and West Indian, are recommended for the subtropical, semitropical and tropical climatic areas respectively. These races can be distinguished from one another using several attributes (Table 1). Hybrids between the varieties are common and of commercial importance. The attributes preferred by breeders in the selection of avocado cultivars are high and regular yields of medium-sized fruits containing small seeds and buttery flesh. Uniform ripening, fruit shelf life and tree size and shape (smaller trees of spreading habit) are also considered (Samson, 1986).

Table 1. Properties of some avocado varieties (after Samson, 1986)

Main attribute	*Specific attribute*	Mexican	Guatemala	West Indian
		----------------Properties by variety-------------		
Oil	*scent*	nice	none	none
Leaf	*size*	small	various	various
	skin	thin	warty	leathery
Seed	*size*	big	small	big
	cavity	loose	tight	loose
Tolerance	*cold*	yes	medium	no
	salt	no	no	no
Fruits	*oil content*	high	medium	low
	maturity (months)	6	9	6

Farmers generally recognize the avocado varieties by cultivar rather than races. Some of these cultivars include, *Hass*, which belongs to Guatemalan race and is self-fertile. The fruit is warty, medium sized, roundish and purple at full maturity. The fruit has a tough, pebbly skin, ships well, has good shelf life and enjoys wide consumer acceptance (Koch, 1983). *Fuerte,* is a Mexican-Guatemalan hybrid with shiny-green pear-shaped fruit that weighs 250 to 450 g with a high oil content (18-26 %). *Booth 8* has large, pear-shaped fruit that turn purple on ripening. Other varieties grown in Kenya are *Reed, Puebla, Pinkerton* and *Simmonds* (Mugambi, 2002). Kenyan farmers produce avocado for food, local markets and export. The fruits are largely grown in the Central Highlands and have been found to be the second in prevalence on farmers' field after *Grewia robusta* (Betser *et al.,* 1999).

One industrial process involving avocado is the recovery of its oil. Avocado oil has a pleasant smell and multiple uses in cosmetics, healthcare products and as a fine lubricant. Both raw and processed avocado oil represent a potential source of income for farmers while its use as lighting fuel may contribute to the reduced dependence upon fossil fuels as an alternative to paraffin (kerosene).

Avocado Oil Extraction

1. Collect mature, off-grade avocado fruits
2. Ripen for 2 days
3. Cut the fruit into pieces and remove the seed (Figure 1)
4. Sun dry the fresh pieces of avocado until brown to black in colour (Figure 2)
5. Wrap the dried pieces in a cloth then use a clamp to squeeze the oil
6. The extracted oil is ready for use as a fuel and burns well in an open lamp

A liter of oil is extracted from between 9 to 11.5 kg, or about 40 to 50 avocado fruits. In Kenya, avocado oil was tested for some of its chemical and physical properties by the Kenya Bureau of Standards and the Kenya Institute of Research and Development (Box 1). Because the avocado fuel produced from this process does not light well with the regular lantern lamps, a special lamp has been designed for the use of avocado fuel (Figure 3).

The harvesting cost of avocados is negligible as many fruit fall to the ground at maturity. Off-grade avocados are inexpensive during harvest seasons or freely obtained from neighboring farms with surplus production.

Avocado production follows peak seasons and the processing of fuel oil from avocado competes with other local uses such as food. Even the low-grade fruits enjoy demand in local market as an inexpensive food and over-ripe fruits have a distinct taste that is preferred by some consumers. The fruit is highly nutritious and lacks harmful fats and cholesterol. The oil is also used locally as herbal medicine for certain health conditions and in the preparation of cosmetics that are not discussed in detail within this chapter.

Figure 1. Mature, sliced avocados ready to be dried for oil extraction.

Figure 2. Dried avocado pieces ready for oil extraction.

Box 1: Attributes of avocado oil

Parameter	**Value**
Density	0.9006 gm/cm^3
Iodine value	87.32
Oil content	100% w/w
Peroxide value	3.00 ml N/kg
Ash content	0.31% w/w
Flash point	103.8^o C

Conclusion

Improving the marketing of avocado fruits will reduce post-harvest losses and improve household income. The efficiency of oil extraction needs to be improved especially for trees that are not rich in oil such as *Hass* and other Guatemalan varieties. The use of a pressing machine to replace the current manual extraction methods will improve the efficiency of oil extraction. The extraction and use of avocado oil as fuel is innovative but its progress is limited by the economics of the undertaking. Already avocado has a number of uses that offer higher returns than fuel. With the current extraction technique, one litre of avocado oil has a value of KSh 200 while the equivalent quantity of paraffin costs only KSh 35. The need to improve on the avocado oil lantern may increase the effectiveness of the avocado oil technology and stimulate demand for its processing among low income households. Better filtration of the avocado oil would allow for its fuller industrial processing particularly into cosmetics.

Figure 3. A simple wick lamp that burns using the avocado oil.

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Chapter 17

Traditional Green Vegetables in Kenya

Paul L. Woomer and Maryam Imbumi

Traditional green vegetables occupy an important role in household nutrition throughout Kenya, particularly in rural areas, as these are the main source of vitamins and provide variety to meals otherwise consisting of maize, beans and occasionally, meat stews. These green vegetables also provide a secondary source of proteins (IPGRI, 1997; Maundu *et al*., 1999). In general, green leaves and young stems are collected, washed, chopped and either steamed or boiled in combination with other vegetables then fried with onions and tomatoes. These vegetables are now being grown in rural and peri-urban areas for market, both locally and for urban consumption and are likely to become more important within urban gardens as well. Yet, many consumers in urban areas as well as Central Kenya consider *sukuma wiki* (or kale, *Brassica oleraceae* var. *acephala*) and Swiss chard (*Beta vulgaris* var. *cicla*), mistakenly referred to as spinach (*Spinacia oleracea*), to be preferred green vegetables. It is hoped that this chapter will provide greater recognition to the traditional alternatives.

Many community-based workers and development specialists mistakenly popularize the use of “indigenous spinach” while referring to some plants that are not actually native to East Africa. “Indigenous” plants are those that have evolved within and spread throughout an area unassisted by humans. Some of the plants used as green vegetables are in fact indigenous, such as cowpea (*Vigna unguiculata*, kunde in Kiswahili), spider plant (*Cleome gynandra*) and crotalaria (*Crotalaria ochroleuca*).

Other popular plants are “naturalized exotics” that have originated elsewhere, but arrived in Kenya many years ago and are now widespread throughout East Africa. Many of the most important crops in smallhold farms of Kenya belong to this category. Maize and beans, along with cassava and pumpkin originated from Tropical America and were spontaneously adopted and spread by farmers throughout the continent of Africa after introduction by early European explorers in the 15th and 16th Centuries. Today many African farmers are unaware that these are not “African” crops. Kale (*Brassica oleracea* ssp. *acephala*, sukuma wiki) and Swiss chard (*Beta vulgaris* ssp. *cicla*) are two important leafy green vegetables originating from Europe and S.W. Asia respectively that are widely grown by East African highland farmers. Yet another category of plants are those that are “pan-tropical" and cosmopolitan. For example, the many types of green vegetable Solanum (*Solanum nigrum* complex) is so widespread, no one is sure of its origin.

To use "indigenous" and "traditional" as synonymous is a mistake because it does not account for the natural and anthropogenic movement of useful plants. From a practical perspective, it does not really mater if a crop is endemic, indigenous or exotic as long as it is valued and contributes to household needs. The term "traditional" encompasses indigenous species as well as widely distributed exotics that have become an important part of the food culture. Farm biodiversity is emerging as an important issue, and special consideration should be given to indigenous crop plants in this regard because it is within a "Center of Origin" that the greatest genetic diversity occurs. For this reason, we refer to the various green vegetables as indigenous, naturalized or exotic in the following section, and leave it to readers to determine whether or not they wish to attach special importance to crops that are truly indigenous to East Africa.

Traditional Green Vegetables: The Plants

Amaranth (*Amaranthus dubius*), mchicha (Swahili), terere (Kikuyu), lidodo (Luhya), ododo (Luo), kelichot (Kipsigis), w'oa (Kamba), emboga (Kisii), kichanya (Taita), doodo (Luganda). A herbaceous annual belonging to the family *Amaranthaceae* with green or red leaves and branched flower parts (heads) bearing small, black, shiny seeds. While originating from Tropical America it is now very widely distributed throughout the tropics. Plants are generally sown straight but may be started as seedlings, transplanted to 20 cm spacing and harvested at a height of 30 cm, requiring six weeks after transplanting.

The leaves are separated from the larger stems and cooked. The cooked leaves contain about 8% protein, 4% carbohydrates and are rich in calcium, iron and vitamins B and C. For example, only 47 g of cooked leaves contain 100% of the minimum daily requirement of Vitamin C (Maundu *et al*., 1999). Many other species of Amaranth occur in East Africa, some are serious weeds but others are also eaten including *A. hybridus* from Tropical America, *A. graecizans* and *A. blitum*. Seeds of mchicha are marketed by Simlaw seeds of Nairobi in 25 g packets although poor germination has been observed within some batches.

Cowpea (*Vigna unguiculata*), kunde (Kiswahili), mathoroko (Kikuyu), likhuvi (Luhya), a lot-bo (Luo), nthooko (Kamba), egesare (Kisii), kunde (Kipsigis), Kiyindiru (Luganda). A climbing, spreading or erect annual herb belonging to the bean family or *Leguminosae (Papilionaceae*). Cowpea is native to Africa where it was domesticated over 4000 years ago. The crop exhibits much variation in growth habit, leaf shape, flower colour and seed size and colour.

Cowpeas are started from seed planted about 20 to 40 cm apart and are often grown as an intercrop with maize. When produced as a green vegetable, it is commonly grown as a monocrop in rows 30 to 40 cm apart with 8 to 12 cm between plants. The dried seeds, fresh seeds, pods, leaves and young stems are edible. Some varieties are good for leaves while others are good for seeds. Some very drought resistant types may grow for two seasons in the farm. Tender cowpea leaves and shoots contain 4% protein, 4% carbohydrates and are rich in calcium, phosphorus and vitamin B. Dried seeds contain 22% protein and 61% carbohydrates (Maundu *et al*., 1999). The leaves may be dried and stored for later use. Cowpeas are generally tolerant of drought and low light conditions, but are very susceptible to a variety of insects and diseases and do not do well in poorly drained and cool areas. Cowpeas that are sprayed with pesticides should not be eaten as leaves. One additional benefit of cultivating cowpeas is its ability to fix atmospheric nitrogen in root nodules through symbiosis with a rhizobium bacteria that is common in most soils.

Crotalaria (*Crotalaria ochroleuca*), miroo (Luhya), mitoo (Luo), kamusuusuu (Kamba), kipkururiet (Kipsigis), oleechei (Maa) lala (Acholi), aubi (Luganda). A short-lived, erect perennial herb growing up to 1.5 metres in height, indigenous to Africa and belonging to the bean family or *Leguminosae* (*Papilionaceae*). In Kenya, it occurs primarily in Nyanza and Western Provinces and can grow at elevations up to 2000 metres but does best in warm areas. The leaves are divided into 3 long, narrow leaflets, the flowers are yellow with purple veins and the pods are short, fat and contain numerous, small yellow to orange seeds. The plant is seldom found in the wild and is grown from seeds cultivated in rows or fertilized, raised beds. The leaves are eaten as a cooked green, usually in combination with other greens because Crotalaria has bitter taste. The leaves contain up to 9% protein. Another species, *Crotalaria brevidens*, prepared in a similar manner has a wider range within Kenya, extending from Eastern Province to Lake Victoria and is distinguished by its wider leaves and longer, thinner pods. Crotalaria is also a nitrogen-fixing legume.

Jute (*Corchorus olitorius*), mlenda (Swahili), murere (Luhya), chikosho (Kambe), namale (Turkana), omotere (Kisii), vombo (Giriama), ntereryan (Tugen), otigo winyo (Acholi), mutere (Lusoga). An erect woody herb growing up to 2.5 meters high belonging to the family *Tiliaceae* and originally from Asia but now naturalized in Africa and Tropical America. The elongate leaves reach 15 cm long with serrated margins and are eaten as a cooked green. The raw leaves contain 5% protein and 12% carbohydrates and are high in vitamins B and C. Jute is usually combined with other greens such as cowpea leaves or Crotalaria as it is somewhat slimy when prepared on its own. Jute seldom grows above 1500 meters above sea level. It is planted from seed in rows and is usually harvested by uprooting whole plants or cutting branches and combining them into bunches. This last method of harvest stimulates the production of more branches. Jute is also used in Asia to make a coarse fibre and the bark and root have medicinal properties.

Pumpkin (*Cucurbita maxima*), malenge (Kiswahili), marenge (Kikuyu), lisebebe (Luyha), risosa (Kisii), ulenge (Kamba), bododa (Borana). A spreading annual belonging to the family *Cucurbitaceae* and native to North America. It was cultivated in Mexico as much as 7000 years ago. This species and the related ones provide pumpkins, squashes, gourds and their leaves are usually used as vegetables. These species which are North American in origin include *C. pepo*, *C. moschata* and

C. mixta. Distinguishing them is often difficult. Pumpkins have long-running, bristled stems, large deeply-lobed leaves often containing white "blotches" and yellow or orange flowers separated into male and female types on the same plant.

Pumpkins are grown from seed by planting in hills 1 to 2 m. apart and prefer well-drained soils that are fertilized with compost or manure. The fruit may rot when in contact with moist soil, so often cut grass or leaves are placed beneath the fruit. Pumpkin is susceptible to leaf fungi (mildews) and virus disease (mosaic), but these usually appear later in the life of the crop. Pumpkin leaves that are sprayed with fungicide should not be eaten as spinach.

The leaves, fruit and seeds are edible, with the fruit usually boiled or steamed and the seeds roasted. The younger leaves are collected and the outer tough skin of petioles (stalk of leaf) removed (together with the large leaf veins) then washed, chopped and boiled. The fruit is variable in shape and color but is often white, cream or green, containing about 70% flesh and several large white seeds. Pumpkin fruit contains 1% protein and 8% carbohydrates, and the dried seeds contain 23% protein, 21% carbohydrates and up to 50% oil, but little information is available about the nutritional characteristics of cooked leaves.

Solanum species (*Solanum nigrum* complex), nightshade (English), mnavu (Kiswahili), managu (Kikuyu), namaska (Luhya), osuga (Luo), isoiyot (Kipsigis), kitulu (Kamba), ormomoi (Maa), ndunda (Taifa), nsugga (Luganda). This plant is an erect, many-branched herb growing 0.5 to 1.0 m high that is widely distributed throughout the tropics. The plant bears thin, oval, slightly purplish leaves up to 15 cm in length, numerous white flowers and usually purple to black, round berries about 0.75 cm in diameter containing many small, flattened, yellow seeds. Plants are established on raised beds from seeds that are planted at a spacing of approximately 10 cm. Solanum plays an important role in traditional medicine in Africa and elsewhere, but the leaves are considered poisonous in some areas of the world so one should be careful about obtaining seeds for planting. Seeds are marketed by Simlaw Seeds in Nairobi under the name Black Nightshade in 25 gram packets and another source with particularly large, tasty leaves is available from SACRED-Africa, Bugoma, Western Kenya (see Appendix).

The leaves are eaten as a cooked vegetable, often mixed with other vegetables and the fresh fruits of some types are also consumed. Some Solanum varieties are preferred for their bitter taste while others are considered "sweet", particularly after being boiled and the water discarded. The raw leaves contain 4% protein, 6% carbohydrates and are moderately high in vitamin C. Many types of Solanum species are fond in Kenyan vegetable gardens including *S. americanum, S. eldorettii*, *S. scabrum* (in picture), and *S. villosum.* The plant's leaves and growth tips are susceptible to mites (very small, sucking arthropods) that result in twisted growth and low productivity.

Spider Plant (*Cleome gynandra*), cat's whiskers (English), saga, mwangani (Swahili), thageti (Kikuyu), tsisaka (Luhya), alot-dek (Luo), saget (Kalenjin), chinsaga (Kisii), mwianzo (Kamba), jjobyu (Luganda), yobyu (Lusoga). Spider plant is an erect herbaceous annual herb with hairy, often purple stems and many branches growing to a height of 1.0 meter. The plant has edible leaves that contain up to 7 leaflets spreading like the fingers of the palm and leaflets growing up to 8 cm long. The flowers are rather showy, long and bearing many small white or pink flowers. The elongate fruit resembles a pod, but is refered to as a capsule, containing many small, dark seeds. Spider plant originated in Africa and Tropical Asia but now has a worldwide distribution, including North and South America, the Far East, Australasia and the Pacific Islands. It belongs to the family *Capparidaceae*. In Kenya, It grows from sea level to 2400 metres. The plant is either cultivated or harvested from the wild, and when cultivated, it is usually grown by broadcasting seeds on raised beds. It is a fast-growing plant that is ready for harvest in as few as three weeks.

The leaves are eaten as a cooked green vegetable, have a mildly bitter taste and contain 5% protein, 6% carbohydrates and are high in vitamins A and C, calcium, phosphorus and iron. The bitter taste is derived from polyphenolics, which constitute from 0.5% to 0.9% of the edible leaf (Chweya and Mnzawa, 1997). The plant is able to tolerate infertile soils and short-term drought but is susceptible to chewing insects and birds. The leaves are usually cooked when fresh but may also be dried and stored for up to two years although this practice greatly reduces the crop's nutrition value. Spider plant is believed to replenish blood and therefore referred to as a 'traditional meat' by some Kenyan communities.

Other, less common traditional green vegetables include traditional kale (*Brassica carinata*), water spinach (*Ipomoea aquatica*), arrowroot (*Colocasia esculenta*) and stinging nettle (*Urtica massaica*). More information on the characteristics and preparation of these vegetables may be obtained from Maundu *et al.* (1999) and Woomer (2002).

FORMAT and the Traditional Green Vegetable Cooking Contest

Organic resources that were overlooked or taken for granted in the past are now becoming recognized as valuable assets by farmers and entrepreneurs. Substantial gains are made in the use of organic resources but these accomplishments seem insufficiently communicated among farmers, entrepreneurs, agricultural extension specialists, grassroot organizations, policymakers and research scientists. The Forum for Organic Resource Management and Agricultural Technologies (FORMAT) was formed in 2000 as an informal association of stakeholders whose common purpose was to popularize innovation in organic resource management. One of FORMAT's goals is to inform the public on how to better conserve, cultivate and prepare Kenya's indigenous and traditional foods. In keeping with this goal, FORMAT frequently includes Traditional Green Vegetable Cooking Contests within its events (Woomer, 2002). The rules of the cooking contest are as follows.

1. Entries must primarily consist of indigenous leafy green vegetables that are boiled, fried or steamed and must be prepared start-to-finish within two hours using no more than two cooking vessels.
2. Each contestant is provided similar cooking facilities but must supply their own pot, utensils and ingredients.
3. Only one entry is allowed per participant in a single contest. Every entry must be accompanied by a list of ingredients and recipe and will be judged shortly after preparation in the presence of the contestant.
4. The following ingredients are strictly forbidden; meat, fish, cheese, canned products, noodles, cocoyam corms and cassava roots (due to the lengthy cooking time necessary to detoxify cassava roots). Cooking fat from animals may be used at the contestant's discretion.
5. Entries are permitted the use of non-indigenous plants, herbs and spices, but excess dependence upon non-traditional ingredients will be penalized during judging.
6. There are three judges, including a head judge, drawn from the scientific, academic or epicurean communities who evaluate the entries on the basis of taste, texture, presentation and any other criteria they deem important.
7. Contestants may be called upon to sample their own entries before judging, and the judges may ask questions of contestants concerning the preparation of the entry. The decision of the judges is final.

The event attracts many interested onlookers from the general public. Many contestants preferred to cook on wood or charcoal fires using clay pots and traditional wooden utensils, a preference that was encouraged as it adds to the atmosphere of the event. After judging, the entries are distributed in small paper plates and sampled by spectators. Winners are announced and prizes distributed by the head judge. Organizations hosting events designed to promote traditional foods are encouraged to include similar contests.

Selected Recipes

Amaranth, spider plant and groundnut relish (*contributed by Adija Baraza)*

Ingredients

1/4 kg	amaranth (1 large bunch)	2 medium	tomatoes, chopped
1/4 kg	spider plant (1 large bunch)	1/2 cup	groundnut powder
2 tbsp	shortening or cow fat	3 tbsp	water
1 medium	onion, chopped	1 tsp	salt

Preparation. Clean and wash both the green vegetables, chop the vegetables, onion and tomatoes and set aside for later use. Heat the shortening or fat and fry the onion until soft and slightly brown. Add the tomatoes, stir and cook until soft. Add the green leafy vegetables, stir, cover and simmer for 20 minutes, stirring occasionally. Mix the groundnut powder into a smooth paste and add to the simmering vegetables, then salt to taste. Cook for an additional 5 minutes. Preparation yields four to six small portions and is best served while hot with *ugali* or mashed bananas.

Cream of nightshade spinach *(contributed by Mathew K. Kwambai)*

Ingredients

1 kg	nightshade leaves	1 medium	tomato, chopped
1 cup	water	1 tbsp	salt
90 ml	cream	2 tbsp	vegetable oil
1 medium	onion, chopped		

Preparation. Pinch the leaves of nightshade from the main stalk while retaining a very small leaf stem. Wash the leaves in a basin and drain off the water. Bring the water to boil and put the leaves into the boiling water for 25 minutes, then remove from fire and drain excess water. Heat vegetable oil in a pan and add the chopped onions, stirring occasionally until the onions are soft. Add tomatoes and the boiled nightshade leaves and cook for two minutes, stirring occasionally. Add the cream and one liter of water, cover and simmer for five minutes. This preparation makes four servings and is best served while hot with *ugali*. An alternative recipe involves the addition of 1 to 2 cups of other traditional green vegetables, particularly spider plant or amaranth, with the nightshades.

Crotalaria and jute with boiled milk (*contributed by Mary Wangila)*

Ingredients

1 kg	crotalaria leaves	1 tbsp	salt
½ kg	jute leaves	1 tbsp	traditional salt
½ litre	water	½ litre	fresh milk

Preparation. Remove the Crotalaria and jute leaves from the stems and discard the stems. Wash Crotalaria and jute leaves, drain and allow to dry for several minutes. Add Crotalaria and jute leaves to ½ litre water, 1 tablespoon of traditional salt and 1 tablespoon ordinary salt and heat the mixture to boiling. Boil the leaves for 20 minutes while stirring occasionally. Add ½ litre milk, stir gently and simmer for 10 minutes. The preparation yields from four to six medium portions and is best served with *ugali.*

Spider plant with coconut milk *(contributed by Maryam Imbumi)*

Ingredients

1 kg	spider plant leaves	1 medium	onion
0.250 liter	water	3 medium	tomatoes
1 tsp	salt		
0.25 liter	coconut milk		

Preparation. Harvest the young spider plant leaves including the stem tips then remove the leaf stalks. Wash the leaves with clean water and cut into small pieces. Place into a pot containing 0.25 liter of water, add 1 teaspoon of salt then vegetables and boil over a medium fire for 10 minutes. Next add 0.25 liter of dilute coconut milk and boil for 10 minutes. When leaves are cooked, mash in pot and add oil (or cow fat). Using a separate sufuria fry onions till brown, add tomatoes then vegetables and 0.25 liter of thick coconut milk (or fresh cow's milk), then cook for 5 minutes, stirring occasionally. Provides 4 to 6 medium portions. Best served with chapati, rice or *ugali*. To mix with other vegetables, boil Amaranth leaves and spider plant separately. When cooked, mix both then mash in one pot.

Recent Commercial and Consumer Trends

Traditional green vegetables are marketed in Kenya's urban areas. Harvesting the relatively small leaves one-by-one is labour-consuming and generally not practiced when traditional green vegetables are grown commercially. Rather, whole plants are harvested when they are 20 to 40 cm in height, tied into bundles and sent to market. These bundles are marketed through both informal (roadside) and formal outlets and it is not uncommon to find bins of traditional vegetables being sold in

Nairobi's largest supermarkets. In effect, selling these vegetables in bundles transfers the labor requirement of obtaining leaves that are ready-to-cook to the consumer and this task is not greatly appreciated. Opportunity exists for entrepreneurs to develop frozen or dried products that are more readily prepared. One such pilot product, Instant Mboga, was displayed at FORMAT-West in 2002 by Alice Masinde. Leaves of various green vegetables, including pumpkin, Solanum and spider plant, were blanched, air dried and then packaged with dried onions and tomatoes. This product cooks very quickly and is difficult to distinguish from the fresh vegetables.

Another approach is to obtain, clean and cook larger quantities of green vegetables and then bag and freeze them. These frozen vegetables may be added to sautéed onions and tomatoes, and different recipes prepared by adding milk, coconut or groundnut as described earlier in this chapter. Processing the leaves then becomes an occasional weekend family activity. Opportunity also exists to prepare these vegetables in a more innovative manner. For example, I recently prepared vegetarian lasagna using a mixture of amaranth, Solanum and spiderplant spinach, and dinner guests were amazed at the results. Whether they are obtained from the home garden or the supermarket, traditional green vegetables remain an important food in Kenya but we must continue to find new and more convenient ways to process, market and prepare these important foods.

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Chapter 18

EM: A Microbial Product for Sustainable Agriculture

Peter N. Chandi

Microorganisms are widely utilized in human medicine and health, food processing, agricultural biotechnology, environmental protection and the treatment of wastes. These organisms are most effective when introduced into a suitable environment containing substrates that match their metabolic needs. Professor Teruo Higa of Ryukus University in Japan identified several microorganisms that promote agricultural production and environmental conservation (Higa, 1993). The microorganisms are packaged as "EM Technology", including a product "EM1"® that is stocked in Kenya by several retailers.

This technology consists of naturally-occurring microorganisms that are compatible with one another and can coexist in liquid culture. The microorganisms include photosynthetic bacteria (*Rhodopseudomonas* spp.), lactic acid bacteria (*Lactobacillus* spp.) and yeast (*Saccharomyces* spp.). When in contact with organic matter, they secrete beneficial substances such as vitamins, organic acids, minerals and antioxidants that beneficially affect plants and other micro-organisms (Table 1). In agriculture, EM promotes crop growth and yield through improved release of plant nutrients, photosynthesis, resistance to plant diseases, efficacy of organic matter as fertilizers and in suppression of soil-borne pathogens and pests. The EM product also reduces offensive smells from industrial and domestic waste disposal sites, inhibits proliferation of harmful microorganisms and vectors such as flies, mosquitoes and ticks and retards the oxidation of metals.

EM is not a substitute for other management practices, rather it may be considered a compatible accompanying technology. It may be combined with other sustainable land managements such as crop rotations, use of organic amendments, conservation tillage, crop residue recycling and biocontrol of pests. In Kenya, this technology is promoted by EM Kenya for use by organic and conventional farmers. In environmental management, EM may be used to treat industrial and human wastes as it controls odors and accelerates decomposition.

Table 1. Some suggested mechanisms responsible for EM beneficial effects.

Organism	Mechanism	Effect
photosynthetic bacteria	induce root secretions	produces amino acids, nucleic acids and bioactive substances, increases mychorrizal activity and root uptake
lactobacilli	produce lactic acid	suppresses harmful organisms in the plant rhizosphere, accelerates decomposition
yeast	excrete plant growth substances	stimulates cell division and accelerates root development

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EM Technology in Agriculture

EM1® is sold in one liter plastic bottles containing a yellow-brown liquid with an acidic pH (<4.0). This product is intended for dilution at rates from 1:100 to 1:1000 or in combination with other materials. EM may be used as a microbial inoculant for a variety of purposes in agriculture (Figures 1 and 2). It accelerates decomposition when applied to green manures prior to incorporation into the soil by ploughing (1:500) or to materials intended for composting (1:100). It may be applied as a dilute solution to irrigation water (1:1000) or to wastes for odor abatement (1:100). EM can also be applied as foliar spray (1:500) to compete with plant pathogens and as a direct soil treatment.

According to Prof. Higa, the microorganisms contained in EM promote more favorable soil microbial populations which decompose organic inputs and soil organic matter and also suppress plant parasitic organisms. Non-symbiotic microbial innoculants are relatively new to organic farming systems and show promise as a means to regulate microbial processes in the phylloplane (leaves), rhizosphere (roots) and soil. Because these processes are complex and biologically-based, the effects of EM technology are not as predictable or consistent compared to more conventional agro-chemicals, but nor are they as destructive to the environment. EM technology is considered “organic” and may be used within certified production systems. Preliminary field trials with tomatoes at Embu in Eastern Kenya suggest that a very large economic return may be obtained from spraying EM onto crops (Table 2).

Table 2. Partial economic analysis of tomato management strategies at TENRI, Embu during the 2001 long-rains (FYM indicates farmyard manure).

Costs and returns	treatment			
	EM	fertilizer	FYM	control
Average yields (kg ha^{-1})	87407	56111	57037	7685
Gross benefit (KSh ha^{-1})	2185185	2185185	1402778	192130
Total variable costs (KSh ha^{-1})	8740	157234	150459	145293
Net benefit (KSh ha^{-1})	2176444	1245543	1275466	46836

Other EM Products and Applications

Figure 1. Applying an EM solution to climbing beans using a watering can at a dilution of 1:1000.

EM extended solution is prepared by mixing EM stock, molasses and water. It is stored in an air tight container for 7-14 days to ferment until the solution attains a pH of below 4.0 and with a sweet sour smell. Its shelf life is normally 30 days after fermentation.

EM fermented plant extract is made by fermenting young fresh weeds with molasses and EM stock. It contains organic acids, bioactive substances, minerals and other useful organic compounds. By absorbing these derivatives, the plant develops antioxidants and improves its resistance to diseases. It should be applied after seedling emergency to control pests and diseases.

EM insect repellant is prepared from molasses, vinegar, distilled spirit and EM stock and stored in a tightly closed plastic container away from direct sunlight for 7-14 days. It should be used within three months after preparation by spraying a diluted solution of 1:200 (100 ml EM: 20 litres) after seed germination.

Figure 2. Applying an EM solution to young pumpkin vines using a backpack sprayer at a dilution of 1:500.

EM compost is made by applying fermented plant extract at 1:100 and sprinkling it onto a compost pile until it contains about 30% moisture. The compost is then covered and left to react for 30 to 40 days, when the compost is ready for application to the filed.

EM fermented livestock feed is made by sprinkling EM onto the feed, mixing and storing in an airtight plastic container for 10-14 days. A sweet sour smell indicates good quality silage while a rotten smell, resulting from excess oxygen, indicates poor quality. Add the fermented feed to the regular livestock feed and use within 3 months.

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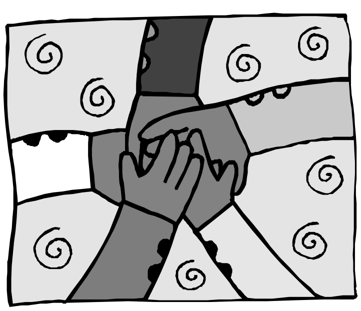
Editors Note. The submission by EM-Kenya was shortened somewhat at the editors' discretion. Several other uses and claims of EM were made by the author, including those involving human health that we were not qualified to review. The crop production claims should be regarded as preliminary as no details were provided by the author concerning the experimental conditions, nor have the findings been published in a scientific journal.

Part 4

Extension and Technology Adoption



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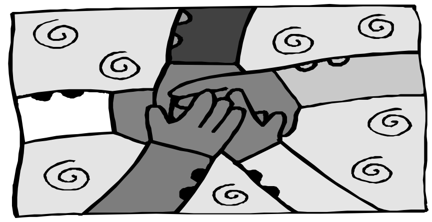

Chapter 19

The Operations of Rural Self-Help Groups

Paul L. Woomer, Musa N. Omare and Eusebius J. Mukhwana

Groups of neighboring farmers share common obstacles and opportunities and it is reasonable that they organize for collective action. The self-help groups that arise commonly devote their efforts to accessing information, learning new technologies and pooling resources to acquire inputs or to market surpluses. Most farmers, however, lack experience in forming self-help groups, particularly with the steps necessary to formalize and register their new organization. The information contained in this chapter is designed to provide guidelines on the establishment and operations of a legally-recognized self-help group in Kenya. Several case studies are presented to illustrate the common features of grassroots groups despite differences in their situations and goals.

Part of the need for grassroots rural organizations in Kenya is related to the collapse of formal extension services to the smallhold agricultural sector. Many years previously, several programs were initiated in maize marketing, fertilizer supply and veterinary medicine but for a complex suite of causes, these services became scattered at best, and virtually non-existent for most (Eicher, 1999). An abrupt introduction of market liberalization and structural adjustment imposed upon Kenya by international donors and lending institutions was partly responsible for the removal of subsidies, but equally responsible was the lack of a new approach to equitable service provision that followed these changes in national policies. Yet, even farmers receiving the best extension services often find it in their common interest to form local organizations aimed at improving their individual farms and their communities (Terrent and Poerbo, 1986). Good farming involves intuition and skill but seldom close-held secrets. Indeed, the willingness of farmers to assist one another is a comforting feature of rural life.

Forming a Self-Help Group

Formalization of self-help groups provides a legal instrument for their activities and a recognized constitution that identifies the groups' mandate and modes of operation. The process of forming a self-help groups may vary but the step-by-step procedure that follows demonstrates how a new group may be initiated, formalized and registered with Kenyan authorities (Figure 1).

Step 1. Identifying common difficulties and mutually-accepted goals. Formation of a group starts with an informal gathering of relatively few persons sharing mutual concerns. These individuals identify common goals, interim officers and a strategy to reach out to the larger community.

Step 2. Obtain information on group registration. The interim officials collect information on how their group could become registered and managed by visiting existing community groups and government offices, in this case the Ministry of Culture and Social Services. This information includes registration requirements, application forms, example by-laws and lists of potential members.

Step 3. Documentation. The interim officials complete application forms that identify a group's name, its objects and intended activities. This document must include the minutes of a planning meeting, including its venue and participants, where a self-help group is formed. Also required is a draft constitution that defines the group's name, mandate, activities and office bearers. A prototype constitution is available from local community development assistants or another registered organization, and then tailored to individual group needs. Application to Kenya's Ministry of Culture and Social Services requires fifteen or more members.

Step 4. First general meeting. Candidate members are invited to a general meeting in order to register with the local organization and to discuss, amend and adopt its constitution and elect office holders. A presiding officer, who is not seeking office, is appointed to conduct the elections according to the group's constitution. Elected officials assume office immediately and all inquiries and activities of the group are thereafter conducted through the elected officials. Groups have at least three office bearers, a chairperson, secretary and treasurer.

Step 5. Application is submitted. Elected officials meet with a local community development assistant or the District Culture and Social Services Officer to formally request registration. They submit copies of the group's minutes, constitution, membership role and elected officials accompanied by an application letter. An application fee of between Ksh 1000 and 2000 is payable when the application forms are accepted. The registration process takes up to four weeks because all applications are approved by the District Officer in charge of Culture and Social Services. In some cases, applicants may be asked to seek the consent of the local chief and district officer before their application for registration is finalized.

Step 6. Commencement of operations. The registration process is complete when the group receives a certificate of registration that empowers them to exercise their respective mandate. From this point, officials are expected to hold regular meetings, design a work plan, identify local and external collaborators, and continue membership drives. The group's success is not by successful registration but rather how effectively it identifies and undertakes tasks that realize the stated goals for community development.

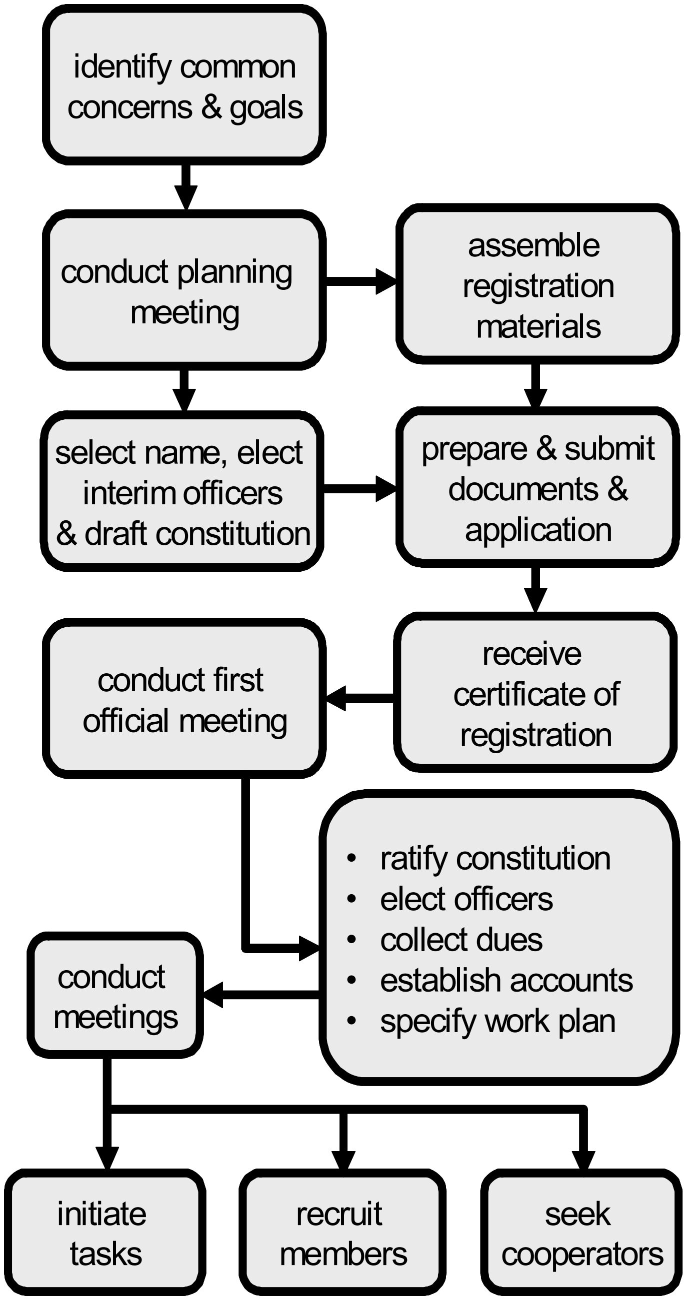

Figure 1. Suggested steps in the formation, registration and operations of a self-help group in Kenya.

Operating an Effective Self-Help Group

Planning group activities is primarily the responsibility of the group's officials and committees that they organize. Activities must be planned in a manner that permits members' full participation and is consistent with the group's rules of operation and goals (Vedeld, 2000). This planning process also identifies new opportunities for collaboration and sustenance of group activities through resource mobilization. It is important to include a monitoring and evaluation plan for the group's activities to ensure that objectives are being realized and activities sustained. Poor planning results in activities that are not cost effective or fail to achieve significant impacts as anticipated.

Self-help groups face the challenge of sustaining the group enthusiasm over time. Frequent meetings promote group cohesion and continuity. Regular elections provide opportunity to members to confirm or reserve their support for group leaders. Long-standing officers becoming bossy may lead to the collapse of a group because all members expect to be treated as equals. Presentations from invited speakers, distribution of sample materials for on-farm testing and social activities also serve to reinforce group cohesion. Officers should politely resist attempts by local politicians and administrators to steer the group toward their own ambitions (Vedeld, 2000), but rather invite efforts that assist in the realization of the group's goals.

Effective leaders are those who promote greater group interaction and constructive dialog. Updates concerning group activities should be communicated to members regularly and all issues raised by members satisfactorily responded to by leaders. Transparent handling of finances and operations is a solid foundation in the group's success, and it is necessary for the treasurer to be familiar with standard accounting procedures. Wider delegation of authority to members through the establishment of committees and working groups inspires greater cohesion and reduces officials' workloads. A balance of roles among men and women is also important in maintaining group cohesion. The social dimension of a group's activities, where song and dance, poetry recitals and skits are performed, scholastic achievement honored or where members support one another through personal difficulties must not be overlooked.

Establishing tasks and collaboration

The work plan of an organization is separated into a series of tasks that are undertaken to achieve its larger objectives. Some tasks may be undertaken through group mobilization, such as pooling resources for land preparation, local marketing or establishing community seedling nurseries. Other production and marketing problems cannot be resolved by that group in isolation. Indeed, one of the major concerns that lead to the establishment of grassroots groups is the need to access new information and technologies. This need often results from weakness in front-line extension services, suggesting that information and technologies will not be delivered to their doorsteps and requiring that the self-help group seek links to other organizations (Omare and Woomer, 2002). Collaboration is readily accomplished through three mechanisms, usually in stepwise fashion; by linking with neighboring groups, by joining networks or planned development initiatives and by developing working relationships with specialized research institutes and development agencies (Terrent and Poerbo, 1986).

Self-help groups mature over time and at different rates, and as they accomplish various goals their reputation grows. Indeed, successful groups stimulate the establishment of new groups, particularly along their geographic margins. New groups form, rather than established groups grow, because the rural poor lack ready access to transportation and communication facilities, so more-localized operations are required. These successful organizations thereby serve as a model for their more recently-established counterparts, particularly when some members belong to both organizations or when officials of both organizations liaise.

Participation within networks and planned development initiatives offers special opportunities to develop fruitful collaboration (Lacy, 1996; Terrent and Poerbo, 1986; Omare and Woomer, 2002). Most networks are founded on the assumption that client groups will become attracted to their activities, and will actively seek collaboration. Self-help groups should take care when joining these initiatives that the goals of the network are compatible with their own needs, but when this is the case, new information and candidate technologies will follow. Collaboration within networks occurs at cost, however, particularly in terms of time and resources required for technology testing, recordkeeping and impact evaluation, and self-help groups must be aware of this commitment from the onset of collaboration.

Many non-governmental organizations specialize in networking with several smaller self-help groups and this may prove an especially fruitful collaboration when their common needs are being effectively combined and planned actions "packaged" for donor investment. At the same time, there is no shame in declining an invitation to join a network, particularly when its activities cannot be related to the local group's priorities. For example, marketing initiatives may be premature for a self-help group struggling to meet household food requirements, or testing mineral fertilizers or pesticides is unnecessary when these inputs are either unavailable or too costly.

Working with researchers poses a particular dilemma because they tend to be driven by different goals and approach issues from a greater level of sophistication than do small-scale farmers (International Federation of Agricultural Producers, 1990). Science is hypothesis-driven, meaning that experiments are designed to either accept or reject a statement describing the relationship between various phenomena (mechanisms). Field experimentation requires contrasting treatments, some of which are intended as controls, and not as possible improved technologies. Furthermore, treatment plots must be randomized within an experimental design to achieve statistical legitimacy and those plots may contain one or more sampling areas within them.

Non-scientists are often mystified by this scientific process, and are inclined to consider all treatments as "recommendations". They believe if a scientist has taken the time to carefully install a particular management on their farm, then it must be credible. Some farmers even have difficulty distinguishing different treatments from accompanying scientific field methods. For example, when crop rows and plant spacing are established using marked lines, they might do the same in adjacent fields and then sense disappointment with the resulting crop performance. Working with researchers requires that both parties be prepared to take extra effort to explain themselves, and that those members in the self-help group possessing a better understanding of science must explain the activities to less-educated members (Lacy, 1996). Most researchers greatly enjoy their time spent in the field, and many farmers welcome occasional distraction from tedious field operations, but this mutual satisfaction must not be confused with genuine confluence of interest between the two parties.

Significant rewards may also be realized by self-help groups through collaboration with researchers. It is usually agricultural scientists who have first access to potentially useful technologies and germplasm. Scientists can better diagnose the hierarchical constraints to crop growth, or separate underlying causes from secondary symptoms. On-farm research projects often require that farmers collect data or document their activities, and these exercises improve recordkeeping skills and their ability to calculate their production costs and economic returns. Successful research collaboration brings prestige to a self-help group that may be translated into future opportunities. Self-help groups must recognize that when the research project is concluded, periodic visits by their scientific cooperator are likely to end. Field researchers must realize that their role within society is to find useful answers to important questions, and that the immediate needs of client farmers should not be overlooked in favor of professional ambition (Nyerere, 1974). A list of practical suggestions to research parties appears in Table 1.

Fundraising and grantsmanship

A group's funds must be accurately and transparently reported, and this task becomes more difficult as sources of funds diversify and accounts grow. But how can a self-help group comprised of relatively poor households raise funds and what opportunities exist to obtain grants and loans? Fundraising begins by imposing modest dues upon new members and requiring that membership be renewed at periodic intervals. These dues, sometimes as low as KSh 50 per year (US $0.67) can provide little more than stationery for officials and tea at meetings, but this is often sufficient to allow for the formulation of plans leading to collective actions. The strength of newer self-help groups may be measured in tasks accomplished and not bank accounts, and pooling labor and physical assets is the best way to

Table 1. Guidelines for successful collaboration between farmers belonging to self-help groups and researchers conducting on-farm studies.

Cooperating farmers should

- Make their own observations concerning field trials and express them at group meetings and to research partners
- Organize local field days that demonstrate the tested technologies to their communities
- Make a genuine effort to understand the scientific basis for treatment selection and sampling procedures so that promising results can become adapted into farm practice

Cooperating farmers should not

- Falsify data collection records, disguise experimental failures or exaggerate claims for compensation
- Remove crop harvests without the knowledge and agreement of research partners
- Expect researchers to engage in lengthy social interactions during intensive field campaigns

Researchers should

- Involve cooperating groups and farmers in an earlier stage of research planning
- Rely upon simplified experimental designs and relatively few treatments and explain which treatments are intended as candidate improved technologies
- Establish a clear timetable and division of responsibility for field operations, data collection and recordkeeping
- Interpret their research findings into terms understandable by client farmers, particularly their costs and returns
- Be prepared to modestly compensate cooperators for their efforts and harvest removal
- Encourage farmers to conduct their own satellite experiments adjacent to the field trials

Researchers should not

- Perform unplanned on-farm field operations without the knowledge and consent of cooperators
- Fail to keep appointments or rearrange schedules without consulting cooperators
- Ignore collaborator's impressions of different management practices, particularly unrealistic reliance upon additional labor, land or expenses
- Exclude acknowledgement of community groups and key individuals within their publications

achieve solidarity. Membership drives are a means of raising funds but do not increase a self-help group's per capita financial resources, rather they mobilize more individuals toward collective action. One such collective action is the bulk purchase of inputs, such as seeds and fertilizers. Local retailers, especially those in more remote locations, sell their products at relatively high prices out of necessity. Group members who pool their cash for purchased inputs are able to place larger orders and obtain lower prices. Group officials may then place a slight charge for organizing that service, for example 10% of the cash saved through bulk purchase, as a means to raise funds for other group activities.

Self-help groups tend to refine or diversify their activities over time (Terrent and Poerbo, 1986). Successful groups that were initiated to accomplish household food security find themselves reorganizing to market modest surpluses. Individual farms may be victimized by opportunistic middlemen offering low prices at the farm gate, but a group of farmers is able to bulk and transport surpluses to better markets. Even at the most local scale, it is more efficient for a few group members to market larger amounts of produce than for many individuals to compete with one another to sell smaller amounts. For these reasons, many self-help groups develop marketing activities that charge modest fees for selling members' produce. Other collective actions may lead to income generation by initiating new enterprises such as raising poultry or irrigating vegetables that would otherwise be beyond the financial means of individual members. Furthermore, self-help groups are able to establish bank accounts to qualify for short-term loans to purchase farm inputs or to initiate new income generating enterprises.

A milestone in the maturity of a self-help group is when it becomes able to generate its own proposals for grants and loans. Many small grants programs exist but identifying suitable donors and meeting their required format and writing standards is no easy task for a group of poor farmers, no matter how articulate they may be (International Federation of Agricultural Producers, 1990). Most rural households have invested heavily in their children's education and one means to reaping returns on that sacrifice is to involve then in preparing proposals and small business applications. Potential cooperators may also be judged on their ability to raise funds for group activities.

The computer revolution is penetrating rural Africa through the establishment of cyber cafés into small towns and trading centers. These facilities may be used to establish free email addresses and to word process and print proposals. Similarly, mobile telephone coverage is rapidly extending into rural areas, after a decades-long wait for land lines. Email addresses and telephone numbers lend credibility to grassroots organizations, as well as allow for more rapid communications. Care must be taken to maintain these contacts because chronically non-operational communications will reflect negatively upon a group as well.

Some pitfalls to avoid

Self-help groups are advised to avoid several common pitfalls. There is tremendous diversity in Africa's agenda for rural development, literally from A to Z (e.g. Agroforestry, Beekeeping, Carbon sequestration, Dairy goats … Vitamin A, Women and Youth group, and Zero grazing) and grassroots groups should avoid establishing overly-complex sets of goals. Furthermore, several large organizations advancing specialized or ideological agendas may manipulate grassroots groups into testing and endorsing inappropriate technologies to secure positions among competing interests (International Federation of Agricultural Producers, 1990). Farmers tend to be practical and skeptical in order to avoid unnecessary risks and their grassroots organizations are advised to behave in the same manner.

Poor time management and lack of punctuality are all too common in Africa. Admittedly, many rural poor are unable to afford wristwatches in order to keep better track of time but if timekeeping was the only problem, one would expect as many to be early for a meeting as late and this is surely not the case. Members should attend meetings on time, officials must start meetings on time and everyone must be careful not to waste one another's time. Poor timekeeping is cumulative, and when immediate tasks are achieved later, then longer-term goals become delayed. At the same time, members who have something important to say should be provided opportunity to do so, but when an individual, including the chairperson, feels compelled to respond to every member's comments, time is probably being wasted.

Everyone is entitled to their own opinion and even those sharing the same set of goals may differ on how these are best prioritized and achieved. Such differences are constructive when they are objectively discussed because this allows for a consensus of opinion to emerge. It is not appropriate to allow past disputes and petty jealousies to become aired during meetings, and those who indulge in repeated selfish or vindictive behavior pose a liability to the group. It is important that leaders develop conflict resolution skills. If necessary, members whose constant feuding interferes with group progress should first be warned and then suspended from the group. At the same time, no one is perfect, so members should demonstrate tolerance to one another's mistakes and idiosyncrasies.

Case Studies of Self-Help Groups

St. Mark Women Group, Amagoro, Teso

Teso lies to the south of Mount Elgon in Western Kenya. It contains infertile sandy soil and until recently, was primarily used for grazing. The conversion to sedentary agriculture resulted from increased population and establishment of land titles but was accelerated by an epidemic of East Coast Fever, a viral disorder that decimated the local cattle population. The St. Mark Women Group was started by

Figure 2. St. Mark Women Group members greet scientists that have come to observe the group's approaches to soil fertility management.

30 church members in 1998 as an outgrowth of a prayer group. Its original goals were poverty alleviation and improved child nutrition. The group has five elected officials; a Chairlady, Vice-chairperson, Secretary, Vice-secretary and Treasurer who are elected for three-year terms. The current membership (2003) is 52 and the group is locally recognized as an effective and equitable community-based organization, in part because of its widely attended field days and its successful efforts in processing and marketing traditional crops.

The group's primary collaborator is the Sustainable Agriculture Centre for Research, Extension and Development in Africa (SACRED-Africa) that initiated a local outreach project in partnership with St. Mark and other local organizations in Teso in 1999. Relying upon participatory methods for problem identification and a simple adaptive research process, progress was made in the areas of composting, soil fertility management, tree seedling establishment, integrated pest management, crop diversity, marketing farm surpluses and gender roles in agriculture. The St. Mark group also serves as one of seven cooperators in the Best Bet Network, a group that evaluates alternative land management recommendations side-by-side on 140 farms in Western Kenya (Figure 2).

After five years of operations, several impacts from St. Mark Women Group are evident. Their rapid bulking and broad distribution of cassava resistant to the mosaic virus promoted food security within the group and among neighboring farmers. When most other cassava in their district was failing, this group had established over 240 ha of cassava throughout the area. The adoption of a maize-lablab relay fallow has demonstrated that sustainable field cropping may be achieved on the worst of N-deficient sands. Traditional green vegetables and small grains that previously were considered a home gardening activity now have established markets. But the benefits from the group's activities extend beyond technical adoption because the members now view agriculture in a more holistic and positive manner.

Members are able to diagnose new problems as they arise and to better apply past lessons to emerging situations. The underlying mechanisms for the degradation of agricultural resources are now better understood, as are the relationships between various conservation measures. As Jenipher Etiang', the group's Chairlady, stated *"We discovered that we had many resources at our disposal that we were not using well and the relationship between the problems that we were having and our present and past actions. It was a turning point in our lives."* The group is frequently visited by members of other organizations from Kenya and neighboring countries, officers from the local Ministry of Agriculture and local politicians who attend field days to make modest donations. Members assist one another with medical and funeral expenses and through small loans because they know their neighbors can now generate income by farming. Even domestic lives have improved, as evident from Jenifer's comment *"Women no longer bother husbands for money to buy salt, sugar or tea leaves and this has improved our family relationships"*.

Siritanyi Farmers Field School, Bumula, Bungoma

Siritanyi Farmers Field School (SFFS) is located in the Bumula Division of Bungoma District in Western Kenya, a smallhold subsistence farming area with sandy and rocky soils that relies upon maize-bean intercrops for household food production. Ironically, the area has favorable market access, being located near the Bungoma District Headquarters and along the main road connecting Nairobi and Kampala. The group was formed in 1998 as a component of the FAO-Ministry of Agriculture Farmer Field School Program that was originally intended to promote pest and disease control technologies. *Siritanyi* is *Bukusu* for "well-established" or "unshakable", a name selected to express their hopes for their newly formed community-based organization.

SFFS was formed by 30 members in 1998 and remains approximately the same size in 2003. Membership is open to all neighboring farmers and requires annual dues of KSh 50 (US $0.68). The group officers include a Chairman, Vice-Chairperson, Secretary, Treasurer and Farm Manager. Officers are elected and serve for three years. The field school is a registered organization with the Ministry of Culture and Social Services. General meetings are held three times a month. The group operates a 0.6 ha demonstrational farm, land provided by one of its founding members. An important function of the group is to access information and new agricultural technologies, a task that is accomplished through broad collaboration with local extension officers from The Ministry of Agriculture, The Farmer Field School Network, SACRED-Africa and other farmers' groups in Western Kenya.

The group has organized collaborative training in various agricultural practices including farm recordkeeping, establishment of soil conservation structures,

Figure 3. Members of the Siritanyi Farmer Field School host visitors from several universities and NGOs to explain their strategy to produce and market higher-value crops.

production of higher-value vegetables, soil fertility management, and maize-legume intercropping technologies involving groundnuts, cream grams and soyabean. The group invented a special plow to create furrows for staggered maize rows that allows for cultivation of these alternative legumes. Crop yields and household incomes have increased from this training. For example, average maize yields have improved from 1.3 t ha^{-1} to 2.8 t ha^{-1} and average monthly family income has risen from KSh 1500 to KSh 4000 due to increased sale of farm produce (US $21 and $54, respectively). These gains have eliminated the “hunger months” from April to June when little food was available to their households and as well as resulting in better diets throughout the year. The success of the field school is now being replicated through the establishment of two other groups; ‘Siritanyi B’ and “Fanya Bidii’ in neighboring locations.

The group assesses its progress based on meeting attendance, farm yields and the incidence of pests and disease and it reaches out to non-member farmers through regular, open field days. Despite its success, Benson Mutambo, SFFS Chairman admits that some mistakes were made. In 2002, the group purchased a bulk order of a hybrid maize variety that was not well suited to the growing conditions in Bumula. This led them to obtain and compare several different maize varieties so that wiser choices may be made in the future. Personal differences and jealousy among members have resulted in some problems in group operations that in turn required its leaders to develop skills in conflict resolution. Clearly, this group learned from these mistakes. The success of SFFS is reflected through many additional indicators. For example, members of the field school have participated in several national and international symposia, including those in Nairobi, Uganda, Ethiopia and South Africa, most commendable for a small group of farmers that organized only five years ago to discover better ways to feed their families.

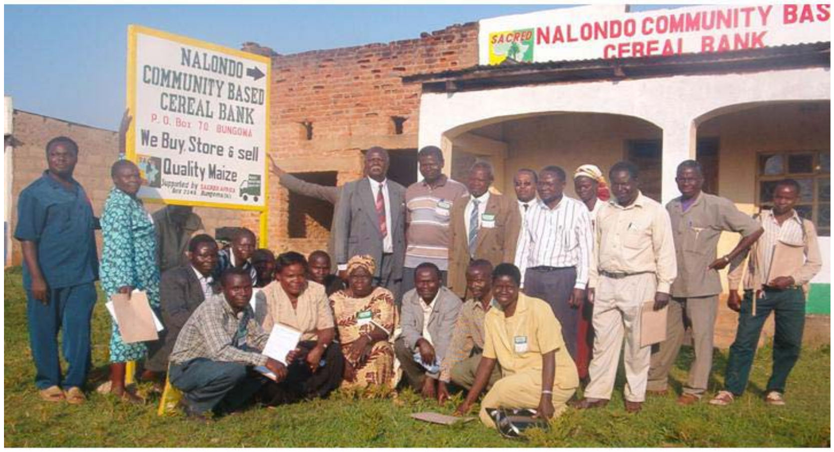

Figure 4. Members of the Nalondo Community-Based Cereal Bank and cooperators from SACRED-Africa pose before their recently-established marketing facility.

Nalondo Maize Marketing Self-Help Group in Central Bungoma

Producing a bumper maize harvest in Central Bungoma is no easy task, but one that can be achieved because of the area's deep clayey soils and well distributed rainfall. The highly weathered soils are infertile, but fertilizers are available and may be combined with domestic manures to offset their high price and meet the crop's nutrient demands. Seeds of well adopted hybrid maize varieties are commercially available, and these varieties are resistant to many of the serious fungal disorders that caused problems in the past. It is not uncommon for a smallhold farm that devotes one hectare (2.5 acres) to maize production to obtain grain yields of 4 tons, with only 1.5 tons needed for household needs. Farming as a business requires that crops not only be grown, but they must also be processed to industry standards and effectively marketed. Individual smallhold farmers find it difficult to achieve this second half of their business operations.

Complicating the situation is a recurrent "good season, bad prices" phenomenon, meaning that immediately following peak harvest prices are extremely low. Some farmers are forced to sell maize surpluses at little or no profit in order to meet other household demands for cash. It is this dilemma that has led to the formation of cereal banks, where farmers combine their efforts to process, inspect, bulk, store and market grain. The Nalondo Cereal Bank is one such group. It was initiated as a component of SACRED Africa's Maize Marketing Movement, has 101 members, elected officers and an audited bank account and it is registered with Kenya's Ministry of Culture and Social Services. Its goal is to stockpile and store maize until later in the year when prices are at their highest, and then to sell the maize for maximum profits.

While the goal is straightforward, their tasks are many. First, farmers must improve the quality of their grain to meet industry standards with strict limits on damaged grain and the presence of foreign materials. Most farmers lack the simple tools required to exclude contaminants and separate off-grade grain. A particular threat is posed by grain borers, small insects that attack maize in the field and then spread throughout the grain after it is processed for storage. Finding buyers is also difficult considering that the largest millers require that suppliers provide quantities of 100 tons or more, and that up-to-date market information is difficult to obtain in the poorer rural areas. Nonetheless, SACRED-Africa and other partners are working with the Nalondo Cereal Bank to overcome each of these difficulties.

SACRED-Africa trained Nalondo's members in maize processing, and designed and distributed the tools necessary to ensure grain quality. Group leaders were also trained in recordkeeping, marketing and leadership. It assisted the Cereal Bank to secure and renovate a 4000 m^3 grain storage facility, and distributed the bags and pest control agents required to suppress borers. It provided a low interest loan of KSh 300,000 (US $4050) so that it may make partial payments to members while their maize is stored as well as purchase additional maize from others. The Maize Marketing Movement has also enlisted marketing support from the National Cereals and Produce Board, the Kenya Agricultural Commodity Exchange (a broker) and United Millers Limited. During the current season (mid-year 2003), the cereal bank expects to market 600 t of maize for a profit of KSh 2 million (US $26,700) above what would be earned if that amount of maize was sold to middlemen when prices are extremely low.

Tom Katenya, recently-elected Chairman of the Nalondo Maize Marketing Self-Help Group, described their situation. *"At first it was difficult to convince farmers to join the cereal bank because many hope for quick benefits and others recall the failures of the previous cooperatives. Now we have registered 101 members and benefited from training in maize processing and marketing. The cereal store is in operation, we look forward to advertise ourselves as a business group and next we intend to diversify into other agricultural commodities. The cereal bank has proposed to save some of our maize for the next hunger period during March, April, May and June."* We wish the members of the Nalondo Cereal Bank good fortune in their collective endeavors and suggest that their approach may prove a useful example to others.

Conclusion

Several of the general principles that were presented in the earlier part of this chapter are illustrated through the three case studies. All groups were initiated to address specific constraints but the scope of their activities has broadened with time. The need of greater household food security was the immediate need that led to group formation for St. Mark Women Group and Siritanyi FFS, but initial successes were translated into the production of higher-value crops and marketing activities. These two organizations have also stimulated the formation of new self-help groups in nearby areas. The Nalondo group was initiated to collectively bulk, store and market maize surpluses, but now intends to handle higher-value crops as well. Because of the investment necessary to collectively process, warehouse and wholesale maize, Nalondo grew in size rather than spawn other groups.

Each group is registered with the Kenyan government, conducts regular meetings and relies on periodic elections to appoint officials. The groups have established bank accounts and telephone and email contacts but are at different stages in developing the capacity to prepare their own reports and grant applications. Each group relies upon membership dues to maintain its core operations, but has also established strong collaboration to implement specific activities. The groups also maintain cordial relations with local government officers but do not rely upon them for financial support. Social activities have differing importance within the groups, indeed the St. Mark Women Group started as a prayer group and acts to preserve traditional song and dance among the Teso community. Marketing associations tend to be more business-minded, but regular meetings also serve to make new acquaintances and reinforce old friendships. These are but three of thousands of self-help groups in Kenya, and were selected in part because of their geographic proximity, sophistication and recognized success, but clearly they reflect very positively upon the crucial role that community-based groups play in African rural transformation.

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Organic Resource Management in Kenya:
Perspectives and Guidelines
Edited by C.E.N. Savala, M.N. Omare
& P.L. Woomer. FORMAT, Nairobi. 2003

Chapter 20

Extension of Organic Resource Management Practices

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Farmers do not necessarily adopt agricultural practices as introduced to them by researchers but select and adjust some elements that suit their farming conditions and goals. Efforts to improve the capacity of farming communities should actively involve them in all stages of adaptive research from planning to conclusion of the project activities. When community participation is coupled with flexible technical options, the role of extension services is greatly enhanced (Chambers *et al*., 1993). A needs assessment to identify and prioritize the needs of the target community should precede any community development interventions. This goal is achieved through a process called Participatory Technology Development (PTD).

PTD is a process of purposeful and creative interaction between farmers, researchers and extension agents. It involves working together as agricultural research and development partners to identify, test, adjust, evaluate and disseminate new agricultural technologies. It builds upon the people's local knowledge and agricultural practices allowing for optimal use of locally-available resources. Farmers' participation in this process is essential as it assists development agencies to accurately identify and prioritize farmers' needs (Van Veldhuizen *et al.,* 1997).

This approach has been adopted by the Sustainable Agriculture Centre for Research and Development in Africa (SACRED-Africa) in working with farmers in western Kenya. Its strategy focuses upon identifying and resolving crop production and marketing problems encountered by farmers, promoting agricultural practices that conserve natural resources, and strengthening the capacity of farmers and rural communities to evaluate existing practices and adapting appropriate interventions. SACRED-Africa also promotes social change that reflects the cultural values, needs and responsibilities of community members.

Need exists to move beyond the project-by-project mode to a system's approach in order to better coordinate and sequence interlinked investments in agricultural research, extension and education. This approach requires public and private managers of separately governed institutions to coordinate decisions on complementary investments because the payoffs have been found to be higher if properly planned. Rather than pursued as independent extension, research or education projects, one deals with whole systems (Eicher, 1999). This needs to be accompanied with the relevant training of professional researchers and extension agents (Lynam and Blackie, 1994). Extension agents need to be engaged in applied research activities as part of their educational development while researchers need outreach experiences. This ensures that a student's formal classroom education is readily related and integrated into the context relevant to the student's subsequent employment in the agricultural sector.

Extension agents need to be educated to perform effectively not only as individual experts but as members of teams where they serve as trainers, facilitators and learners (Lacy, 1996). Training has to shift from narrow subject programs to interdisciplinary problem-solving approaches. Integrated strategic planning across related agencies with similar mandates and priorities at national and regional levels is an important strategy for research and extension collaboration both within and across government agencies, NGOs, universities and the private sector. This would give researchers and extension agents more exposure to different areas and improve their participation in decision-making, especially in the sustainable management of organic resources.

Extension and Farmer Innovation

In the past, the approach of most agricultural programs was to develop and teach farmers a set of pre-determined innovations that would increase productivity assuming that having adopted these "top-down" practices, the people would continue indefinitely to conduct farming at the new, higher level of productivity. This approach is flawed. SACRED Africa experience shows that productive agriculture requires a changing mix of technologies in order to realize agricultural development. Farmers should be encouraged to develop their own practices and in ways that they understand. The goal of agricultural extension programs should be to train and motivate farmers to teach each other various innovations from a "basket of options" and encourage them to improve on those innovations themselves. By learning to become teachers of these new technologies, farmers can spread them throughout their localities in a manner that does not require external stimulus.

The farmer-to-farmer extension approach has revealed that the relationship between a farmer and extension agent may be influenced by extension messages learned from past interactions. Poorer farmers with little education are often apathetic as attempts to improve their situation have failed in the past. To change this attitude, it is fair to initiate extension projects involving simple technologies that have been proven successful under similar circumstances. Any intervention that fails will confirm their fears that their conditions cannot be improved. In addition, most farmers learn by observing the experiences of others. Extension agents should cover new subjects at the time farmers recognize the need this information. Extension agents then state their instructional objectives from the onset and how their interactions are likely to address the farmers' situation. The trainer should move step-by-step, starting with farmers' knowledge and abilities regarding the technology, the resources available for implementing the technology and problems that could be encountered (Lynam and Blackie, 1994). SACRED-Africa uses this approach to introduce technologies such as composting, crop rotation and post-harvest handling to the farming communities in Western Kenya.

Often, it is useful not only to present the new skills verbally but also to demonstrate them and give farmers an opportunity to practice them because farmers learn better from observation than from lectures. Extensionists should not expect farmers to deviate much from the way they 'do things' but should improve their skills to solve problems and reach their farming goals. Educating farmers is often a more important task in extension than the actual transfer of technology. Farmers who understand the consequences of their own practices as a cause-and-effect relationship are empowered and better prepared to confront new situations as they emerge.

Extension and Technology Adoption

Studies in Sub-Saharan Africa reveal that development strategies comprise a mixture of food self-sufficiency, profit maximization, risk aversion and sustainability of farm production (Eicher, 1999). Increased population pressure and resource degradation have led smallholder farmers to rely upon the most conservative and inexpensive technologies and consequently, limiting the adoption of many improvements with a known capacity to increase crop yields and farm incomes (Jager *et al*., 1999; Woomer *et al*., 2002).

The dependency on indigenous technologies enables farmers to cope with the various changing environments and sustain farm productivity. Furthermore, indigenous crops may allow for the development of new farm enterprises as these crops become better marketed and commercialized (Figure 1). These technologies are relatively efficient at low productivity levels and are favored by farmers when prices of outputs are low, prices of inputs high and infrastructure underdeveloped. In the long term, however, these technologies alone cannot be relied upon to efficiently exploit the agronomic potential of soils in Sub-Saharan Africa and sustain food security. Integration of indigenous technologies with science can greatly improve natural resource management.

Adoption of new technologies is largely determined by the characteristics of the household (education, social status, attitude, inherent skills and resource endowment), its objectives, together with the characteristics of the technology such as its relative adoption, profitability, compatibility, complexity and viability (Rogers, 1983). External factors such as infrastructure and geophysical conditions also determine the adoption of specific practices but the technology should fit local circumstances. According to Fujisaka (1993), farmers may fail to adopt new innovations for six general reasons.

The innovation addresses the wrong problem. Sometimes the innovation addresses issues that may not be relevant to the immediate production constraint especially when the problem has not been correctly identified. Although farmers easily identify problems of soil nutrient depletion and soil erosion, other problems associated with production may be more difficult to identify.

Figure 1. A farmer in Western Kenya who maintains diverse amaranth germplasm for the production and local marketing of seeds.

Farmers practice is equal or better than the innovation. Some of the technologies offered to farmers perform poorer than the farmers' own management. This may arise when technologies have not been tested in regions with different agronomic and ecological systems or when they have been developed in isolation of alternative solutions.

The innovation does not work or creates other problems that work against farmers' interests. An example drawn from Teso district in Western Kenya (Figure 2) reveals that when improved fallows were introduced as a means of improving soil fertility, one of the introduced species *Crotalaria grahamiana,* was widely attacked and extensively defoliated by caterpillars (*Amphicalla pactolicus*). Because this caterpillar would occasionally move to other plants to pupate, the farmers feared that the pests were attacking these crops. This infestation was of concern to farmers beyond the actual threat it posed but nonetheless is likely to restrict their acceptance of similar innovations in the future.

*Extension fails***.** Extension agents may fail to present an innovation correctly causing its rejection. They may also target farmers who may not have the capacity to use the technology. A common practice by extension agents to work with "progressive farmers" may mislead researchers and extensionists on the choice of the appropriate innovations to recommend and promote to the larger diverse community of farmers.

The innovation is too costly. Farmers frequently reject innovations that are too labour and capital intensive because they lack the time, energy and cash to meet requirements of the new practice. Soil fertility management practices such as mulching, tree biomass transfer and bench terrace establishment have limited impacts due to their unrealistic labor requirements. They compete for labor with other proven farm activities. For some innovations, the costs are immediate while the benefits accrue in the longer-term. Most smallhold farmers are comfortable with innovations that give benefits within the near-term as their planning horizon tends to be determined by immediate household needs.

Figure 2. Extensive defoliation of a newly introduced crotalaria by caterpillars generated distrust of improved fallows among farmers.

Social factors. Social factors such as insecure land tenure systems and gender imbalances may limit farmers from adopting some innovations. Farmers lacking clear title to land refrain from investing in conservation measures or tree planting. Production of crops that require frequent and often unsuccessful trips to local markets may be viewed as acceptable because of their social opportunities.

Communicating Innovations

Effective research and development that involves smallhold farmers require communication techniques that improve the ability of farmers to adopt new technologies, learn from what others are doing and overcome barriers between researchers, extensionists and farmers. Workshops and farmers' group meetings are commonly used strategies that assist to foster local initiatives (Figure 3). Visual aids such as product samples and specimens can be displayed to farmers to facilitate dialogue. Frequent interactions between households and specialized groups clear misunderstandings related to complex social and cultural norms that affect resource use and enhance appreciation of new ideas and technologies (Figure 4).

Figure 3. Members of a self-help group in Western Kenya invited agriculturalists to explain an innovative maize-legume intercropping arrangement prior to field testing in the next season.

Extension messages have to capture and maintain the attention of farmers for the duration of the message and this can be realized through seeing, hearing, touching, tasting and smelling. Communication designers should take into account these factors when preparing extension messages. Commonly used methods include the mass media (newspapers, magazines, radio and television), diagrams, sketches and posters; farm demonstrations; farming groups; and, individual farmer extension. The choice of method for communication of extension messages depends on the technology, the ability of extension agents and accessibility of client farmers. Each of these methods has advantages and disadvantages but their combined use results in greater impact from extension.

Figure 4. Rapid assessment of technology adoption by farmers; a) farmers field testing an innovation in 2001 (standing) and b) those adopting the innovation in 2003.

Conclusion

Farmer participation in planning and execution of extension work improves the impact of extension, technology dissemination and adoption. Constant communication among key players must be maintained and delivered in ways that are understandable to farmers. Farming constraints must be carefully identified and prioritized, to enhance subsequent uptake of technologies that should, in principle, compliment the farmers' practice and solve, not aggravate, a production problem.

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Organic Resource Management in Kenya:
Perspectives and Guidelines
Edited by C.E.N. Savala, M.N. Omare
& P.L. Woomer. FORMAT, Nairobi. 2003

Chapter 21

The Role of Community Composting Groups in Nairobi

Jacob K. Kibwage and Grace M. Momanyi

Kenya's capital city, Nairobi, has experienced rapid growth both in terms of population and physical expansion. The physical area of Nairobi expanded from 3.84 km^2 in 1900 to 684 km^2 in 1963, which is the current official size of the city. As the boundaries were expanded, the city population increased from 16,000 to about 2.1 million persons between 1910 and 2000 (Republic of Kenya, 2001a). About 50% of the Nairobi residents live below the poverty line and are concentrated in peri-urban and slum areas characterized by limited amenities and unhygienic living conditions (Republic of Kenya, 2001b). Such rapid urban growth has caused deterioration of solid waste management services in the city resulting in environmental pollution (Kibwage, 2002). The Nairobi City Council, which is the legal authority responsible for waste management, has no capacity because only 40% of the amount of solid waste generated by the city is collected and disposed. This poor state of solid waste management services in Nairobi is attributed to insufficient financial outlays, shortage of equipment and unfavorable institutional and organizational arrangements. Furthermore, there is an absence of a systematic and integrated approach to tackling the waste management problem. The attitudes of poorer city residents toward environmental cleanliness are also a contributing factor (Kibwage, 1996; Peters, 1998). An urgent need exists for new methods of waste handling and promoting fuller environmental awareness.

By 1986, some of the Nairobi residents able to pay for refuse collection opted for private companies that serviced the high and medium income estates. The low-income residents were required to adopt other strategies to improve and maintain sanitation in their neighborhoods. Hence, by 1992 small-scale community-based composting groups emerged in Nairobi's slum areas including Korogocho, Mukuru-Kayaba, Dandora, Kibera, Mathare and Kangemi. Despite these positive developments by both the private and community sectors, piles of solid waste in open spaces and overflowing refuse containers are all too evident in most residential, commercial and industrial areas of the city. As the magnitude of the task grows, the city council and the government continue to place emphasis upon self-financing of cleansing services rather than enacting policies that sustain recycling activities of the informal sector.

Figure 1. Garbage accumulation in Nairobi's residential estates is an environmental and health hazard to city dwellers.

Constraints Faced by Composting Groups

The distinguishing socio-economic characteristics of composting groups members examined include sex, age, education and training. Most of the composting groups members (92%) are women. Because of the nature of the waste collection occupation, women rely on the few male members or hired labourers to do heavy manual jobs like transportation of organic wastes from the collection points to the composting sites. However, women play a larger role in composting activities in the city. This is in line with Agenda 21 of the Rio Declaration on Environment and Sustainable Development which recognized that the effective implementation of all programs aimed at sustainable development, would depend on the active involvement of women in economic and political decision-making processes (UNEP, 1995). The mean age is 42 years while the modal class is 41-45 years. The older members typically seek the assistance of their husbands and children or casual workers for heavier manual labour. The levels of education attained by the members of composting groups are low. We observed that 46% had no formal education and 37% and 11% had primary and 'O' educational levels, respectively. However, it is encouraging to note that 5% and 2% have 'A' level and college/university education, respectively. The low educational levels among the composting groups members negatively affect their productivity due to lack of basic technical skills and limited ability to learn new composting techniques. This problem is partly resolved through an on-the-job training strategy. So far this strategy being used by NGOs has benefited about 71% of the members. Nevertheless, appropriate training is still required to ensure that consistent and higher quality compost is regularly produced by the groups.

Although the composting activities of the composting groups are self-financing, the groups have financial problems because the sale of compost is not a sufficient source of income for long-term capital investments. They also derive their incomes from membership fees and donations from NGOs or individuals that visit their sites, however, these sources are unreliable and unpredictable. Seasonal variations in the demand for compost cause financial problems because the current market outlets for compost are limited to urban farming. The groups need assistance in the wider marketing of their compost and promotion of the virtues of composting to urban residents for landscaping and as a potting mixture. Composting groups have not had access to credit facilities such as bank loans because they lack securities. Development research also indicates that women groups are often discriminated by financial institutions (UNEP, 1985). It must be noted that composting in the city is an attractive venture for the community-based groups because of the financial and technical support from the NGOs. When the donor funds through NGOs are exhausted, the activities of the groups may likely collapse because they cannot sustain their operations through compost sales.

The Role of Composting Groups in Solid Waste Management

The solid waste in Nairobi comprises 70% readily-biodegradable matter with the remainder being paper and cardboard (13%), plastic and rubber (5%), glass and stones (4%), metal (5%) and the non-classifiable fine materials about 3% (Republic of Kenya, 1985; Kibwage, 2002). Potentially harmful substances such as used electric batteries and razor blades are also present but in low concentrations. This composition makes the Nairobi waste quite suitable for composting after sorting. The percentage of compost obtained from a given pile is determined by the level of training of group members, watering and aeration patterns, presence of soil and the types of composting ingredients. Approximately, 28% of the raw material is lost by leaching, evaporation and conversion to gas during the composting process. All these processes imply that the organic waste is reduced by about 93% at source with only 7% disposed of as residue (Figure 2). Although the benefits of such waste reduction are difficult to quantify, the environmental and economic benefits are clear because composting reduces landfill space requirements, while less financial and manpower resources are used during the collection, transportation and disposal of the waste (UNCHS, 1989). Research findings suggest that urban organic waste recycling has the greatest potential of solving waste disposal

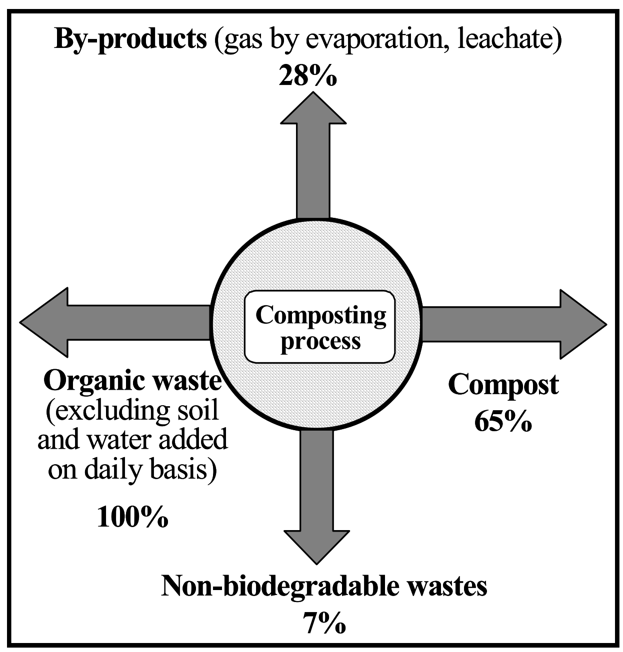

Figure 2. A simplified input-output compost scheme (after Kibwage, 1996).

Table 1. Reasons for joining composting programmes among 184 respondents in Nairobi (after Kibwage, 1996).

Reason for joining	Frequency
Promoting sustainable agriculture	0.29
Generating income through composting	0.73
Creating environmental awareness about waste disposal.	0.91
Improving local sanitation and health	1.00

problems (Maxwell and Zziwa, 1992; Lardinois and Klundert, 1993; Peters, 1998; Kibwage, 2002). Members join their groups with the aim of improving the health and sanitation of the community (Table 1) but may also seek to create environmental awareness on the hazards caused by improper waste disposal. Composting reduces open piles of garbage in narrow streets resulting in reduced populations of rats, mice, snakes, cockroaches, mosquitoes and flies, but also prevents blockage of drainage systems. Promotion of environmental awareness on better waste disposal is achieved through public lectures in churches, schools, colleges and universities. The groups also train individuals and households on the techniques of small-scale community-based composting and separation of wastes at the household level, further contributing to environmental outreach.

Decomposition of organic wastes in open dumps and in stagnant water causes pollution and health hazards, and leachates in the soil lead to pollution of ground and surface water. Open dumps are associated with health and fire hazards including smoke in the slum areas. But, such hazards have drastically reduced in Dandora, Korogocho and Mukuru-Kayaba slum areas after the groups started their composting and sanitation programmes. Solid wastes eroded into the Nairobi River are also reduced. Despite this positive environmental role, inorganic waste, especially polythene papers and plastics, remain a problem to the residents because group members are most interested in organic compostable wastes, however infrequent turning and inadequate monitoring of the compost piles cause bad odours.

Composting Procedure

Composting is a reclamation process that involves activating and controlling the biological decay of organic waste in order to obtain an agricultural soil conditioner. The composting procedure involves four steps: collection of organic materials, building and processing the compost pile, screening for uniformity, and marketing of compost.

Three categories of materials are collected; dry vegetation, green (wet) materials and soil. Dry vegetation includes weeds and crop residues. Dry vegetation is used for adding carbon and improving texture of the compost. Green waste include fresh weeds and leaves, bones, egg-shells, fruit and vegetable peelings, animal and poultry manure, banana and potato peels and maize meal. Soil may be added to improve compost texture. Organic materials that are not considered for composting include meat and animal fats, fish, seeds, bleached paper, diseased plants and dog and cat faeces. These materials are not collected because they decompose poorly, contain potential pathogens or attract pests and vermin to the site. All the collected materials are hand sorted at the composting site to remove these unwanted materials.

Open pile composting is the most common method employed by the composting groups in Nairobi. The steps used in preparing and processing compost follow.

1. Select a 1.5 m x 1.5 m area under the shade of a tree or polythene sheet. The cover shelters the compost pile from direct sun, strong winds and heavy rains.
2. Clear and dig the area to a depth of 15-30 cm. Deeper digging permits excess water and heavy rains to drain, allowing for better aeration.
3. Apply a 7.5 cm layer of coarse dry vegetation such as maize stalks, banana stems and tree branches to allow air to pass through the pile.
4. Add a 10 cm layer of chopped and fine dry vegetation
5. Add a 5 cm layer of green waste and cover it with a 2.5 cm layer of soil to reduce the odor and keep away flies and other pests.
6. Add more layers of dry vegetation, green waste and soil until the pile is 1.2-1.5 m high. Each layer of materials should be watered.
7. In the dry season, make the top of the pile flat and rounded during the rainy season. Cover the pile with a sheet of polythene paper to protect it further from winds and to conserve moisture. During dry seasons, the pile is watered every morning and evening to promote the activities of decomposing organisms.
8. Drive a long, sharpened stick diagonally into the middle of the compost pile. The stick is used to monitor the composting process. The pile is turned once every week. The compost is ready for use when it turns dark-brown, and has no unpleasant odour. The composting process requires approximately 4 to 6 weeks.
9. When the compost is ready, large and non-decomposed objects are removed by passing the compost through a wire mesh (Figure 3). The large objects are either added in the next compost pile or disposed. A mesh size of 5 mm results in finer-textured and more uniform compost, but 10 mm mesh allows for more rapid sieving and greater recovery of finished product.
10. After the screening process, the compost is packaged into 20 kg bags and sold for approximately KSh 200 (= US $2.67). Larger quantities of compost are marketed at a considerable discount.

Socio-economic Benefits of Composting

Although a majority of the group members join their groups with the aim of earning a living through composting, only a small fraction (3%) actually depend upon composting as their main occupation. Other members have varying sources of income including employment in the civil service, private sector or are engaged in small-scale business or urban farming. Environmental protection succeeds when people make a living out of it and this is essential in the planning and implementation of community-based composting projects. Estimates of operational costs and revenues from the Nairobi's composting groups indicate that production of 6800 kg of compost requires about KSh 3320, hence a production cost of about KSh 0.5 per kg. Even at a sales price of KSh 3.50 per kg, substantial profits may be made, sufficient to pay full-time members up to KSh 7000 per month.

The activities of composting groups have contributed to the generation of employment opportunities for the urban poor. For example, The Kuku Women Group employs two full-time workers as well as other casual labourers. The social role of small-scale community-based composting groups is inherently intangible and complex. Nevertheless, the groups are agents of organizational and institutional development within the low-income urban communities. These composting groups represent a significant step in terms of social organization and environmental awareness (Peters, 1998; IIRR, 1998) and from a developmental perspective, this community mobilization is as important as accompanying local income generation.

Technical Issues in Composting

Nairobi's small-scale community-based composting groups face multiple technical problems during collection, transportation and composting of organic wastes. Members of The Kuku Women Group separate their wastes at the household level while non-members are encouraged, but not required to practice source-separation. In either case, sorting is a labor intensive and rather unpleasant task compounded by lack of suitable space and foul odors. The number of non-member households voluntarily separating wastes remains low due to lack of additional incentives and conservation awareness, with some non-members demanding to be paid for their effort. Lack of a policy on source-separation of solid wastes and a general sense of irresponsibility on the part of residents adversely affect composting because sorting is crucial to upscale and improve the safety of waste recycling (Lardinois and Klundert, 1993; Mougeot, 1996). Source separation also reduces the weight and moisture content of solid waste, easing its handling and transport.

Insufficient labor exists because many of the workers are old and less able to move waste materials over modest distances. The major means of transportation used by the composting groups are wheelbarrows with a carrying capacity limited to 40 to 50 kg. There are approximately 10 group members per wheelbarrow, requiring that sacks, plastic bags and traditional baskets also be used for collection and transportation. The use of wheelbarrows provides ready access to the narrow streets and pathways in poorer residential areas and is the preferred means to locally transport wastes. Too few wheelbarrows result in additional toil and reduce compost production capacities.

Monitoring the temperature, aeration and moisture content of compost piles relies upon too much guesswork rather than established procedures. There is need for more exact standards in terms of compost texture and moisture and nutrient contents, as well as better labeling, before these composts can become extensively marketed. Lack of space for efficient sorting, composting and packaging operations also poses a problem to many small-scale community-based composting groups.

Figure 3. Members of Kuku Women Group of Nairobi screening mature compost through a wire mesh prior to packaging and marketing.

The groups have no long-term plans for capital investment, primarily because they lack a permanent title to land for their operations. Too often, composting locations lack sufficient boundaries that would otherwise reduce offensive smells emanating from the sorting areas and younger compost piles. This situation has forced many composting groups to search for alternative composting sites farther removed from residential areas, confounding their transportation difficulties. Composting requires regular addition of water and the groups spend about 18% of their total expenditure on watering. Lack of adequate drainage in most areas of the city, combined with steep slopes may cause compost piles to be washed away during heavy rains. Composting sites usually are not planned and, ironically, environmental impact assessment is seldom considered when selecting locations for these recycling operations.

Compost Markets and Institutional Support

Availability and access to outlets for the finished product is fundamental in the success of any composting activity. However, lack of market for the compost is a major constraint facing the groups (Table 2). Most of the compost lies at the sites for extended periods because the market is irregular and seasonal with moderate sales occurring during the planting season. Poor marketing research, weak advertising

Table 2. Frequency of operational constraints reported by 67 members of small-scale community-based composting groups in Nairobi (after Kibwage, 1996).

Constraint	Frequency
Lack of capital (equipment and finance)	0.37
Lack of composting materials	0.27
Lack of political support	0.16
Environmental constraints	0.10
Lack of market for compost	0.05
Other constraints	0.05

and poor public access to the composting sites negatively affect compost marketing. In addition, many gardeners are reluctant to use compost made from urban domestic wastes. Nonetheless, this compost sells for as much a KSh 10 per kilogram (US $0.13) and the price has approximately doubled over the past decade. Opportunity exists to widen the market for these composts by better packaging and promoting a more uniform product to urban hobbyists and the organic farming movement.

Kenyan legislation is not supportive of composting activities in urban areas. Under the Public Health Act (Republic of Kenya, 1972), a manure heap may be deemed to be a nuisance, in which case the Medical Officer of Health must serve a notice on the person responsible for the nuisance to remove it at the latter's expense. Similarly, composting programmes lack political support from the local and central governments. Apart from the few allocations of small plots to the composting groups, the city council has not integrated composting activities within its solid waste management system. Neither subsidies nor financial and technical assistance are forthcoming from local government. Urban farmers, the largest category of potential customers of this compost, often lack land tenure and may be harassed by authorities. These factors serve to reduce their demand for organic fertilizers which in turn destabilizes the production and marketing of compost (Foeken and Mwangi, 1998; Maxwell and Zziwa, 1992). Although the central government recognizes the environmental benefits derived from composting domestic wastes, few real policy incentives are being extended to these groups to facilitate their operations.

Conclusion

About 70% of Nairobi's solid waste is organic, indicating its suitability for composting. Small-scale community composting groups are concentrated in the low-income slum areas where neither the city council nor the private companies appear interested in investing in waste management. The benefits derived from small-scale community-based composting groups in Nairobi range from reducing the amount of solid waste collected for disposal, improving community health and sanitation, restricting environmental pollution, promoting environmental awareness, creating employment and additional income-generating activities

Figure 4. Plastics recovered from sorted domestic wastes may be recycled into a wide range of useful products such as handbags (a), hats and waste bins woven from clear polythene or fence posts (b) and roofing tiles remolded from darker plastics. The photographed products were produced by the Kayole Environmental Management Association, Nairobi.

(Figure 4) and facilitating urban agriculture. The small-scale composting programmes are popular in the management of solid waste because of the financial and moral support from NGOs.

Enactment and implementation of a policy on source separation of solid wastes and solid waste management legislation to support organic waste recycling and its application is recommended. Political support is urgently needed if small-scale composting programmes are to succeed. The Ministry of Agriculture must assume a leading role in market research, quality standards and run demonstration projects. Opportunity exists to enhance synergies between urban agriculture and other urban sectors through multi-stakeholder consultations on urban agriculture policy, planning and management. Public education on the advantages of using compost in agriculture and its environmental benefits in both rural and urban areas need to be promoted with the use of video shows, radio, newspapers and magazines, television programmes and public campaigns. Apart from farming, other compost outlets such as horticulture, tree nurseries, parks, cemeteries, lawns and playgrounds should be pursued to expand the market for compost. Financial and technical support is urgently required in form of loans, donations, equipment and training by government, NGOs and urban authorities to the various groups.

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Organic Resource Management in Kenya:
Perspectives and Guidelines
Edited by C.E.N. Savala, M.N. Omare
& P.L. Woomer. FORMAT, Nairobi. 2003

Chapter 22

The Organic Agriculture Movement in Kenya

Musa N. Omare and Paul L. Woomer

Organic farming entails the avoidance of chemically-manufactured farm inputs and reliance upon locally-available organic materials as a means of conserving farm resources and controlling crop pests. It strives to maximize returns to available organic resources rather than optimize economic return per unit land through purchased, manufactured inputs (Njoroge and Manu, 1999). Organic farmers view themselves as not only protecting nature, but as part of it, and they arrange farm enterprises to provide food that is intrinsically better for human consumption (Kotschi *et al*., 2003).

The Organic Agriculture Movement developed in Europe as a reaction to industrialization and concerns that conventional farms relying upon manufactured agricultural inputs were "poisoning" consumers and destroying the environment (Kotschi *et al*., 2003). Initially, farming based upon ecological principles provided "safe" food to like-minded consumers through local markets but as the movement grew, so too did the need for consumer protection through certification because "organic" goods were being transported longer distances to command a premium price. Europe's Green Movement is in large part a political manifestation of the organic philosophies. Strict adherence to organic ideology requires that households arrange their lifestyles in a manner that emphasizes self-sufficiency and avoids all food and even textiles that are not produced through "organic" means. Most recently, the organic farming community has denounced the use of genetically-modified organisms in agriculture.

To outsiders, organic adherents appear dogmatic and aloof, in part because they judge, and denounce, much of conventional society along spiritual and ideological grounds. Nonetheless, these adherents are prepared to pay a premium for their beliefs and almost all organic foods cost more than their conventionally-produced counterparts. It is this commercial side to organic agriculture that attracts entrepreneurs, including those in developing nations. Keen businessmen realize that most Western consumers do not consider ideological "baggage" when selecting food for their families, but instead seek assurance that it is healthy rather than harmful. Commercial farms in Africa are establishing large-scale organic enterprises targeting European markets, and these farms are willing to greatly alter

Box 1. Frequently Asked Questions on Organic Agriculture in Kenya

What is organic agriculture? Organic agriculture is the practice of farming that prohibits the use of manufactured chemical inputs to crop and livestock production in favor of naturally-occurring products and biological processes.

What is organic certification? This is the process that standardizes products and processes as organic. In the past, certification was awarded through external parties but recently production and marketing standards were established by the Kenya Organic Farmers Association (KOFA, 2002) and the Association for Better Land Husbandry (ABLH, 1998).

Is organic agriculture an established industry in Kenya? The market for organic produce in Kenya is very small, and any seller can claim that their product is "organic" without certification. Some large commercial farms are certified for export to the European Union. There are only 494 ha under certified organic management, representing only 0.002% of agricultural land in Kenya (Walaga, 2003).

What does organic certification cost? The cost of certification constrains the sector's growth. A small to medium-sized farm will pay about KSh 31200 and KSh 28900 (total US $800) for export licensing and inspection in the first and second year of operation, respectively.

Why do certified organic products attract premium prices? Certified organic products are safer to eat because they more frequently contain less pesticide residues (18% of those tested) than conventional products (71%). Higher prices reflect greater production costs to meet production and certification standards.

Is organic farming more productive than conventional farming? Not necessarily, organic farms in the US report their yields to be 5% less than conventional farms. Adding 2 t compost per ha on 115 farms in Western Kenya during 2002 increased maize and bean yields by 31%, but this was still 14% less than when recommended rates of mineral fertilizers were applied. For each 2.3 kg of compost added to the soil, an extra 1 kg of food was produced!

their crop production strategies in order to become certified for export. Ironically, the poorest of African smallhold farmers inadvertently comply with the precepts of organic agriculture when they never apply mineral fertilizers, instead relying upon manures, and when plant and livestock disorders are treated with traditional plants rather than purchased veterinary medicines, but it is virtually impossible for them to have their produce certified as "organic" because of the safeguards in place to ensure quality control.

Soil Fertility Management in Organic Agriculture

Soil fertility management within organic farming systems in Kenya relies upon numerous, and often complex technologies. Recycling nutrients through composting is a central tenet in organic farming (KIOF, 1990). The basic advantages and disadvantages of composting remain the same between organic and conventional farms. Composting concentrates nutrients from a wide range of readily-available organic resources into organic fertilizers containing reduced populations of harmful organisms and weed seeds. This central advantage to composting may be offset by its large requirements of labor and water, and by the variable and often unknown nutrient content of the finished material (IIRR, 1998). Some restrictions are placed upon how, and how long "certified" composts are prepared. For example, European regulations require that composts prepared from plant materials that were sprayed with chemical pesticides, or manure from livestock receiving manufactured pharmaceuticals must be processed for at least six months before they may be applied to certifiable crops.

Some soil fertility management technologies acceptable to organic farmers are deeply rooted in traditional farming systems as practiced prior to European contact. Traditional crop mixtures that combine cereals, nitrogen-fixing legumes and other crops reduce farmers' risks, suppress weeds and pests and support soil fertility (IIRR, 1998). The addition of livestock manure to soils is a viable alternative to mineral fertilizers when the manure is available in sufficient quality and quantity (Lekasi *et al*., 1998). Heavy mulches offer immediate benefit in terms of weed suppression, erosion control and greater moisture infiltration, and as these mulches decompose, nutrients are also released to the soil in a timed manner (Kanyanjua *et al.*, 2000). Other technologies are shared with conventional agriculture, particularly with those land managers practicing Integrated Nutrient Management. These overlapping technologies include crop rotation, green manures, improved fallows, cover crops, reduced tillage and the addition of raw agricultural minerals (Vanlauwe *et al*., 2002) but not the addition of manufactured chemical fertilizers.

Many technologies appear to be unique to the organic farming community and may involve complex manipulation of locally-available resources. "Double digging" involves sequential hand cultivation to soil depths from 0.6 to 1.3 meter in conjunction with large amounts of compost (KIOF, 1990). The resulting raised bed is heavily mulched and doubtless provides an excellent media for crop roots, but at an extreme labor requirement, and this practice is inappropriate for sloped lands, or those with extremely infertile sub-soils (IIRR, 1998). Similar effort and returns are expected from the "nine-maize hole" where 0.36 m^2 areas are excavated to 0.6 m depth and then partially filled with vegetation. The soil is then mixed with 10 kg of compost, the hole refilled and planted with maize seed (IIRR, 1998). This practice is not only labor demanding, but requires over 13 t compost per ha and utilizes relatively little of the total soil volume. Plant and manure teas are a third practice that is widely promoted among the organic farming community. Fresh manure or green leaves are fermented in water for 10 to 21 days and then diluted 2:1 with water before being applied as a liquid fertilizer. Tithonia and comfrey are two plants that provide useful teas (KIOF, 1990). While the process is simple, again the water and labor requirements are large, and poorer farmers may lack the large containers and watering cans needed (IIRR, 1990). One common feature to these three soil fertility management practices is their intensive reliance upon labor and organic material to such an extent that one may wonder whether these practices are better suited for home gardening than full-time farming.

Pest and Disease Management in Organic Agriculture

Organic farming methods disallow the application of manufactured chemicals for the control of pest and disease, rather plants are protected through preventative and defensive practices. Passive prevention assumes that healthy crops are less susceptible to pest and disease and fertile, moist, well drained growing conditions will lead to fewer plant disorders. Improved biological control results from promoting natural enemies of the organisms that cause plant disorders. Four types of natural enemies are recognized; parasitoids, predators, pathogens and weed-feeders. Applying natural substances to repel and disable pests and diseases is also accepted by the organic community.

Parasitoids and predators are similar except that at least one stage of a parasitoid's life cycle is spent within the host pest while predators simply prey on plant pests and other insects. As a result, parasitoids tend to be very specific in host range and predators attack a wider assortment of prey. In addition, parasitoids tend to be smaller than their hosts and predators are larger than their prey. Most important parasitoids are wasps but others are flies, beetles and other insects. Predators of insect and mite pests are primarily arthropods that include beetles, lacewings, flies, midges, spiders, wasps, and predatory mites. Insect predators are found in both above and below ground environments in agricultural and natural habitats. A common garden predator is the ladybug, a red or orange beetle with black spots that consumes harmful aphids, mites, scales and thrips. Both parasitoids and predators are killed by chemical insecticides, but greater disruption in the life cycle occurs with parasitoids because of their restricted host range (Hoffmann and Frodsham, 1993).

Even pests have diseases, and their bacterial, fungal and viral disorders offer opportunity to control them. Most insect pathogens are extremely specific and as a result will not affect other beneficial organisms. Unlike chemical pesticides that immediately disable pests and beneficial organisms alike, microbial insecticides are specific and slower acting, requiring more time to debilitate its target. Relatively few pest pathogens are commercially available, but this form of control offers exciting potential for the future (Weeden *et al*., 2003). Some insects also consume weeds although the release of these insects must be carefully considered to determine that crops will not also be attacked. An effective weed-feeder should be prolific, a good colonizer within a particular environment, have strong negative effects on the target weeds and be species specific (Emge and Templeton, 1981). An example is found in the successful release of the smooth water hyacinth weevil (*Neochetina eichhorniae*) around Lake Victoria in 1995 to control water hyacinth, an aggressive aquatic weed.

Organic farmers refer to the application of natural products that repel and destroy pests and disease as "defensive". Vegetable oil and soap, often combined with garlic and chilies, will repel or kill many smaller insects. Botanical pesticides may be prepared from pyrethrum, tobacco and neem (IIRR, 1998). An organic pesticide produced in cultures of *Bacillus thuringiensis* and marketed as Thuricide or Dipel effectively controls caterpillars. Diatomaceous earth controls slugs, snails and other soft-bodied pests by cutting their bodies, causing dehydration. Sprays of baking soda and sulfur are accepted by the organic community to control fungal disease. Clearly, several alternatives to chemical pesticides are available but, as these materials are usually less toxic, the timing, placement and manner of their application becomes more critical.

Raising Organic Livestock and Poultry

Guidelines also exist for rearing animals in a manner that is acceptable to the organic community. Meat, dairy products and eggs must be derived from animals that are provided feed from plants that are also raised following organic practices. Livestock and poultry may not be treated with antibiotics or other manufactured veterinary pharmaceuticals, however, they may be vaccinated against infection and treated with natural products that repel and remove parasites. Animals must never be given hormones or other growth stimulants (OFRF, 2003).

The housing and treatment of animals is very important in organic husbandry. Regular access to the outdoors must be provided in a manner that allows animals to express their natural behavior. Organic advocates maintain that many animal pests and diseases are confounded within densely populated quarters where natural control agents are absent and that these stressful living conditions further predispose animals to disease. Emphasis is placed upon preventing disease through balanced diets and access to nature.

The validity of these assumptions concerning organic animal husbandry, and their relevance to Kenyan farmers is uncertain. Refusing diseased animals veterinary medicines because these products are not "natural" is unethical, particularly when practiced by individuals who readily seek medical treatment for their own ailments. No acceptable organic alternative is available for some intestinal parasites, forcing "organic" ranchers to use conventional dewormers or risk the health of their herds (Macey and Grace, 2000). Wild animals are also affected by parasites and disease, and indeed, exposing domestic cattle to antelopes may result in the transmission of East Coast Fever. Condemning the use of manure obtained from animals that are treated with veterinary medicines places unreasonable restrictions upon organic resource utilization and may adversely affect smallholds' food security, particularly when other alternative nutrient-rich organic materials are not available.

Organic Farming and Kenyan Smallholders

The principles of organic farming and sustainable agriculture coincide, but they are not identical as the latter does not condemn chemical inputs. Sustainable agriculture is the management of agricultural resources and production to satisfy changing human needs while conserving the natural resources and maintaining the quality of the environment (Vukasin *et al.,* 1995). Conservation agriculture seeks to minimize the use of external chemical inputs in agricultural production in order to preserve the natural ecosystem.

Declining soil fertility resulting from continuous cultivation of smallhold farms and the need to conserve and build natural resource capital and biodiversity has contributed to the interest in organic agriculture. The Organic Movement views itself as a better alternative to the Green Revolution, which relies heavily upon mineral fertilizers. Organic proponents argue that the application of chemical inputs causes environmental pollution in the soil through acidification and altered biological activities. Others cite the failure of chemical fertilizers to maintain soil structure and soil organic matter as inherently non-sustainable (Harris *et al*., 1998). In contrast, the application of organic inputs supplies substrate to soil biological processes that in turn strengthens the resilience of soil to provide plant nutrients, maintain soil structure, retain water and detoxify agents harmful to plant roots and soil organisms (Woomer *et al*., 1994).

The liberalization of Kenya's agricultural sector in the early 1990s led to increased of prices of farm inputs as parastatal subsidies were withdrawn. This situation caused many smallholders to rethink their production strategies and question their need for fertilizers. Organic inputs were promoted as a replacement to fertilizer by emerging non-governmental organizations (NGOs), many of which developed sophisticated extension programs in organic agriculture designed to sustain smallhold farms (Hamilton, 1997; Harris *et al*., 1998). But there is no specific government policy on organic agriculture in Kenya. Civic organizations presented recommendations to this effect during the preparation of the country's Poverty Reduction Paper and the Rural Development Strategy in 2002. To a large extent, African governments have not incorporated policies on organic agriculture with the needs of food security and rural development, rather it is viewed as providing higher-value horticultural exports (Kotschi *et al*., 2003). Perhaps this is attributable to the difference in experience, as their Organic Agriculture Movement did not develop as a reaction to African industrialization, but rather in an attempt to learn from the environmental mistakes made elsewhere and to provide organic products to growing export markets.

Organic Farming Organizations in Kenya

Several non-governmental organizations (NGOs) champion the organic farming movement in Kenya. These groups include the Kenya Institute of Organic Farming (KIOF), Manor House Agricultural Centre (MHAC), the Association for Better Land Husbandry (ABLH), the Sustainable Agriculture Community Development Programme (SACDEP) and the Kenya Organic Farmers Association (KOFA). These organizations have formed networks that provide training and information to numerous allied grassroots (Figure 1) groups but some are also involved in production, processing and marketing. To some extent, these NGOs have

Figure 1. Extension of organic agriculture technologies is conducted by several organizations on double-digging (left) or organic vegetable production (right).

established geographic domains where they advocate organic agriculture in their respective part of the country.

KIOF was a pioneer in Kenya's organic agriculture movement and is based in Juja, near Nairobi**.** It was established in 1986 to promote organic agriculture among smallhold farmers through training and awareness creation with focus on youth, women and self-help farming groups. KIOF currently works with approximately 20000 farmers belonging to 1000 grassroots groups and maintains demonstration centers in five locations of Central and Rift Valley Provinces. KIOF works with other NGOs, government departments and research organizations in this initiative. The institute has published several booklets on smallholder organic farming practices (KIOF, 1990; Njoroge, 1994; Njoroge and Manu, 1999).

MHAC was established in 1984, is located in Trans Nzoia district near Kitale and leads Kenyan organizations in training on organic agriculture. These training programs focus upon Bio-Intensive Agriculture (BIA) in food production using deep soil preparation and recycling of organic matter into the soil (Figure 2). The Centre offers a two-year certificate course. MHAC also organizes one-week workshops for farmers and six weeks to three months courses for NGO and government extension workers. Its training programs also provide skills in livestock production, appropriate technology, small business management and agroforestry.

ABLH was founded in 1994 to assist farmers' groups in soil fertility management and the processing and marketing of organic products. Its headquarters are located in Nairobi with branch offices in Kakamega and Kerugoya. It initiated an Organic Matter Management Network (OMMN) to promote soil fertility management practices and later initiated processing and marketing of farmers produce under the label *Conservation Supreme*. Unfortunately, production could not be sustained and coupled with low demand for the products, the initiative collapsed. It is presently collaborating with the Soil

Figure 2. Manor House (above) and other organizations maintain permanent demonstrations on organic farming at their centers and in farmers' fields.

Association of the United Kingdom to establish a local organic certification system (ABLH, 1998).

SACDEP was initiated in 1992 to provide training in natural resource management and rural income generation. It has headquarters in Thika and project activities covering Central and Eastern Provinces of Kenya. It runs a demonstration center within its headquarters and also installs on-farm demonstrations on organic farming. The NGO works through farmer field schools and rural self-help groups and publishes a quarterly magazine on organic farming, *The Trumpet*. SACDEP hosts the Participatory Ecological Land-Use Management Association (PELUM), a network of East and Southern Africa NGOs involved in sustainable agriculture.

KOFA was initiated by farmers participating in the KIOF extension and training program. It also operates as a forum for promotion of organic agriculture in Kenya with active participation of farmers and other stakeholders. The association published organic farming standards for its members based on standards by International Federation of Organic Agriculture Movements and European Union (KOFA, 2002). It is also developing its capacity for collective marketing of farmers' organic produce to European countries.

Conclusion

Questions surround the advantage of a Kenyan smallholder's strict compliance with organic practices in absence of certification. Granted, organic management practices are effective in that satisfactory crop yields may be obtained while relying upon locally-available organic resources. But these crops are produced in a more labor intensive and tedious fashion, and for smallholders to simply reject the entire suite of Green Revolution technologies on unproven ideological grounds is likely not in their own, nor their developing nation's best interest. This situation changes when organic certification is coupled with access to reliable organic export markets because organic practice leads to a market-oriented enterprise that offers greater returns than does subsistence farming. For this reason, it is extremely important that local certification and marketing opportunities accompany the grassroots developmental activities that lead farmers toward organic agriculture.

Expanded organic agriculture also requires that acceptable farm inputs become commercially available. For example, Kenya is the world's leading producer and exporter of pyrethrum, a natural insecticide produced by the pyrethrum daisy *Chrysanthemum cinerariaefolium*). Approximately 11,000 t per year of the flowers of this plant are processed by the Pyrethrum Board of Kenya (2003) into an extract for export to developed nations. This exported pyrethrum extract is then incorporated into several products including aerosol insecticidal sprays, mosquito coils, pet shampoos and organic insecticides. Pyrethrin is the insecticide of choice for many household applications because of its extremely low mammalian toxicity and the export revenues derived from it are an important part of Kenya's economy (Thijssen, 1997). Ironically, pyrethrin insecticides are not being locally-produced for use in Kenyan agriculture, instead farmers are advised to prepare their own "teas" from pyrethrum flowers and combine them with soapy water (IIRR, 1998). Perhaps an opportunity is being lost by not locally processing some of Kenya's pyrethrum into commercialized natural products intended as lower-cost, safer replacements of imported chemical insecticides.

Finally, organic resource management must not be confused with organic agriculture. Admittedly, an organic farmer must optimize organic resource use simply to survive but, from an integrated resource management perspective, a land manager who mobilizes organic materials in conjunction with manufactured farm inputs has provided no less an environmental or economic service than another who shuns the use of farm chemicals on ideological grounds.

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Organic Resource Management in Kenya:
Perspectives and Guidelines
Edited by C.E.N. Savala, M.N. Omare
& P.L. Woomer. FORMAT, Nairobi. 2003

Chapter 23

Organic Product Certification

Peter Kanyarati and Bodil Moselund

The global market of organically-produced foods is estimated to be US $11 billion, with organic imports from developing countries calculated at US $500 million (IIED, 1997; Blowfield, 1999). In recent years, there has been an increasing demand in the European Union for fresh produce all year round (Barret *et al*., 1997). Response to this demand has involved the sourcing of both conventional and organic produce from developing countries. It is likely that this demand will continue to rise over the coming years (Dolan *et al*., 1999; Browne *et al*., 2000), offering opportunity for the African smallholders to improve their livelihood through involvement in market-oriented organic farming.

Some policy issues and certification schemes geared primarily to organic production in developed countries do not encourage the inclusion of the resource-poor farmers (Heid, 1999; Harris *et al*., 2002). An added complication is the existence of competing and sometimes incompatible certification schemes for ethical, fair and organic trade (Blowfield and Jones, 1999; Browne *et al*., 2000). There has been initiatives within the International Federation of Organic Agriculture Movements (IFOAM) to develop a framework for associations of small-scale farmers that will enable them to establish and develop internal control mechanisms in order to overcome the current problem of certifying co-operatives (Heid, 1999).

Terms and Concepts in Certification

Organic farming refers to the farming system and products derived through cultivation and husbandry that eliminates the use of chemical pesticides and processed mineral fertilizers. It involves establishing sustainable agricultural practices that better co-exist with natural systems. Lampkin and Padel (1994) define organic farming "*as an approach to agriculture where the aim is to create integrated, human, environmentally and economically sustainable agricultural production systems, which maximize reliance on farm-derived renewable resources and the management of ecological and biological processes and interactions, so as to provide acceptable levels of crop, livestock and human* *nutrition, protection from pests and diseases, and an appropriate return to the human and other resources employed*". Detailed descriptions of the principles and practices of organic farming may be obtained from Lampkin (1990), Neuerburg and Padel (1992) and Lampkin and Padel (1994). The existence of legislation, standards and certification procedures makes organic farming distinct from other sustainable agriculture approaches.

Organic quality is that which has been produced, processed and handled in compliance with organic standards set out by various certifying agencies. Such standards have been outlined by Article 11 of European Commission Regulation (EEC 2092/91) and the IFOAM Basic Standards for Organic Agriculture and Food Processing. Certification is a system or procedure by which the conformity of products, services, systems and processes to applicable standards is determined and confirmed (Rundgren, 1998). Basic Standards are the minimum requirements that a producer must meet to become certified. All the standards applicable to the particular farm and enterprise must be met before the operation may be certified as organic. Basic standards are different from "recommendations", which are practical suggestions for producers to implement in organic farm, food and fibre systems. Recommendations are promoted as good agricultural processing practices.

Organic Agriculture and Value-Adding through Certification

Organic agriculture as a business is quite expensive to initiate and sustain, but the potential benefits outweigh these costs when markets are accessible. The practice of organic agriculture is intended to foster biodiversity and sustain soil fertility as well as minimize environmental damage and the use of non-renewable resources. Besides the production and ecological benefits of organic agriculture, now there is the rapid development of the market for organic produce. The markets are well established in developed economies but require certification of produce as "organic" from local and international producers, thus the process of organic resource and produce certification. Certification creates or enhances trust between trade partners. It adds value to the production process besides the economic and socio-ecological benefits.

The livelihood benefits and opportunities far outweigh the costs and constraints of the involvement of resource-poor smallholder farmers in organic production and trade (Harris *et al*., 2002). These benefits include better prices, new market access, parallel development of new products, greater environmental knowledge and generation of social capital.

Growers are paid a premium price for organic produce that carries an international certificate and is destined for an export market. The value of the premium paid for certified organic is calculated as a percentage over and above the conventional price. For instance, the Dutch Agro Eco consultancy, working on behalf of EPOPA program in Tanzania, have found through financial analyses of their projects, that smallholders enjoy a 15-30% higher farm gate price for organic produce (Van Bleaker and Tullip, 2000). The premium reflects the "organic" quality of the produce, as well as the cost of meeting certification requirements.

Organic farmers who access export markets generally obtain higher prices from a more stable market for their products. A good example is Mirichi Organic Farmers Association (MOFA) in Kirinyaga district where members are able to export to Switzerland organic produce such as plantains and macadamia nuts although these enterprises have not been developed for the purposes of export. The establishment of certified organic producers within smallhold communities also stimulates additional activities including large-scale production of compost and biopesticides and the supply of packaging and labeling materials for export shipment. This benefit is different from the premise of "organic by default". It is believed that organic production in Kenya is in response to a lack of farm inputs. This premise is strengthened by the activities of such institutions as KIOF and SACDEP which have concentrated in marginal croplands and deliberately avoided high potential areas that are better placed to benefit most from certification. Projects funded by development agencies promote indigenous knowledge which can also be incorporated into active organic farming.

In order to achieve international certification, one option for smallholders is to organize into formal producer groups with an internal system of audit and control. There is much evidence that, in working together to achieve accredited status and an effective control system, farmers build up capacity in organization, management, marketing, and financial planning as well as the techniques of organic practice. The rigorous requirements of international certification that need extensive training and development activities can be seen as beneficial in terms of accumulated social capital.

The Process of Certification

The purpose and activities of certification is to guarantee that certain requirements are met. It is different from regulation by state authorities, which seeks to disclose violations and take legal actions against offenders. Certification is administered at all levels, from production through processing to retail sales. Thus certification covers the producer, who has to be familiar and comply with production standards, accepts to be inspected and maintains acceptable production records. The production system including sites and processes must be inspected, the product handling process and finally the product itself has to be certified as organic and be understood so by the final consumer through labeling. The criteria and minimum requirements for organic food production by farmers are outlined in the IFOAM Basic Standards for Organic Agriculture and Food Processing.

Although IFOAM has set the standards, certification and inspection is conducted by various agencies that have been accredited by it or other agencies such as the European Commission. There is also national or local accreditation usually conducted by national governments or organizations for local organic certifiers (Harris *et al*., 2002). The certification process adapted from Rundgren

(1998) is presented in Box 1. The key issues that affect the certification process include standards, rules and procedures, inspection, management of certification process and handling of violations, information and labeling, neutrality and costs of the process and its recovery by both the certifier and producer. These issues should be handled carefully so as to make the certification programme acceptable and efficient.

Box 1. Steps in the certification process

1. Producer requests information from certifier
2. Certifier sends application package
3. Producer submits application
4. Application is screened by certifier
5. Certification contract is signed
6. Certifier assigns inspector
7. Inspector conducts inspection visits
8. Assessment of inspection report
9. Certification decision is made
10. Certificate issued to producer
11. Monitoring and periodic inspection
12. Renewal of certification

Certification of Organic Products by the European Union

In order to be marketed in the European Union (EU) as organic, goods that are imported into the EU from outside the union, must meet strict production and procedural standards, as well as specific import rules, which are outlined in Article 11 of Regulation EEC 2092/91. The general principle applied is that of equivalence. Agricultural production, processing, documentation, inspection and certification are required to be of equivalent standards to EU regulations. The regulations governing import of organic produce apply to crop and livestock products, both unprocessed and processed. The regulations do not have to be identical, but must prove comparable in effectiveness. This allows countries outside the EU to develop their own organic food production and certification systems. Inspection of all stages of the import chain including production, processing, export and import must be upheld.

Import under Article 11(1)

The EU laws allow registration of a non-EU country operating production rules and systems of inspection equivalent to those within the union. Registration requires an official diplomatic request to the European Commission in Brussels by the third country government. Applications from private bodies do not suffice. Registration means inclusion on a list. Countries recognized under regulation (EEC 2092/91), Article 11(1) Annex 94/92 are currently Argentina, Australia, Czech Republic, Hungary, Israel and Switzerland. Inclusion in the list is for a fixed term and it requires renewal.

The EU sends missions to check every 4-5 years that the countries still comply with EU regulations. Within these countries, there are inspection and certificate issuing bodies recognized by the EU. These can issue a certificate allowing the product to be imported into the EU by an importer approved by the competent body of the EU member state. In most cases, the approved inspection and certificate issuing bodies are the same and there are currently two in Argentina, seven in Australia, two in the Czech Republic, two in Hungary one in Israel and two in Switzerland. The inspection and certification bodies may be government departments or NGO's. Being a listed country greatly facilitates the exporting process. Although each consignment of organic produce under Article 11(1) requires a certificate issued by an authority or body listed in Annex 94/92, there is no need for the importer to provide any further details, or evidence of inspection and certification in the country of origin.

Import under Article 11(6)

Soon after implementation of regulation 2092/91, the procedures for accessing the EU market through Article 11(1) were found to be ineffective and inhibited trade. This led to enacting of Article 11(6) under which importers may apply for an import authorization. The onus is very much on the importer. The EU does not process applications for import authorizations; they are investigated and approved by the competent authority in each of the member states. This measure was originally regarded as a provisional arrangement until 31 July 1995. However, its applicability has been extended in a number of occasions and most recently to 2005. Import authorization must be obtained for each importing country. There are some differences in criteria employed by different EU members in determining EU equivalence. Article 11(6) functions quite well but EU member states cannot agree on what constitutes equivalence, and apply their national standards. Although each country assesses equivalence, there is a process (Article 14) under which one country can dispute authorizations awarded by another country. Such disagreements can be resolved and a common position secured through negotiations in the EU headquarters in Brussels.

Import authorization is generally not required for every individual consignment but names the inspection body, producers, processors, exporters and importers. Authorization may be open ended or closed. Authorization may also be revoked. Minor changes, such as the addition of another related product from the same produce, may be added to authorizations, but substantial changes in the inspection body, product, producer, exporter or importer require fresh authorization. Once within the EU, organic produce may be re-exported to other member states without requirement for further authorizations. If an import authorization request (OB6 form) is received, for instance, by United Kingdom Register of Organic Food Standards (UKROFS) with inspection by a previously unchecked body, then equivalence is carefully checked. UKROFS do not charge for their services. When authorization to import is granted, all other EU countries are notified. Once authorization is given by one country for a producer inspection body, exporter combination, then this is likely to be accepted by another country although a full import authorization request has still to be made.

Although the majority of Article 11(6) authorizations name European inspection bodies, these may have contributed to the process in three different ways. First inspection is done by visiting European inspectors and in Kenya it is through group certification by the Soil Association of the UK. Secondly, inspection may be conducted by a local consultant employed by an European body such as the Organic Food Federation of UK, which has a similar arrangement with the Association for Better Land Husbandry (ABLH) in Kenya. Also, inspection can be carried out by a local office of a European body, through local staff and perhaps visited only once a year by a representative from the European certification body.

Certification of Organic Products in Kenya

Resource poor farmers face several constraints to adopting certified organic farming practices. In most cases, the cost of certification and annual inspection is prohibitive. Farmers and their local organizations lack detailed knowledge of organic practices and EU requirements, especially those imposed upon exports. Furthermore, these regulations are inflexible and in some cases inapplicable to smallhold farming systems. Local markets for organic produce are small and disorganized and labeling procedures are inconsistent. Lastly, stronger recordkeeping skills are necessary to meet certification requirements. Establishing certification through accreditation of local inspection organizations is crucial in overcoming these constraints.

The need for local certification

Local certification is seen as one way of reducing costs to smallholder farmers as it eliminates fees levied by international organizations from developed economies. The partnership between Association for Better Land Husbandry of Kenya and the Soil Association of UK led to a local certification scheme but it collapsed, in part because it relied upon visits by European inspectors. Article 11(6) countries must either pay for international inspection or use locally accredited inspection bodies to undertake the audit, which must satisfy EU regulations. International inspection can be very expensive and looking toward other African nations for certification services is not particularly helpful. For example, South Africa Certification Limited charges KSh. 40,000 (US $550) per inspector, a fee that does not include airfare, accommodation and other expenses that must also be paid by the producer!

Local certification systems have other advantages such as knowledge of local conditions and the ability to communicate in local language. Inspection visits are more effective if unannounced but this is difficult with overseas inspectors. Local inspection bodies have also difficulties in obtaining and maintaining international recognition. Many importers need to advise producers to use international inspectors in order to ensure the market for their produce. Producers may not be able to choose the least expensive certification bodies as importers may insist on the use of a particular certifier because of EU approval and the demand of multiple retailers.

Institutions in organic certification in Kenya

Organic agriculture certification in Kenya has been pursued by Kenyan non-governmental organizations involved in sustainable agriculture. According to IFOAM (2001), Kenya has 16 registered member organizations involved in organic farming. Some of these organizations are community-based, non-governmental and church organizations. However, the ones that have initiated certification schemes include:

- Kenya Institute of Organic Farming (KIOF) has a Soil Association (UK) trained certifier and its main target is farmer training and a two-year training program for the youth on organic farming and certification.
- Association for Better Land Husbandry (ABLH) promotes organic agriculture and is involved in certification on behalf of the Organic Food Federation (OFF) of the UK. It has two fulltime certifiers based in Nairobi and Kakamega.
- The Kenya Organic Farmers Association (KOFA) is a registered farmers lobby group whose members are trained in organic farming practices. Their main interest is to link its membership to markets. In September 2002 , KOFA, with the assistance of KIOF published the Kenya Organic Standards which represents a significant move towards a local certification scheme.
- Other organizations which have shown an interest into organic farming certification include the Sustainable Agriculture for Community Development Program (SACDEP), in Thika, Central Kenya.

Currently, some local producers have been identified and certified to produce various organic food products for the European market. These include

- Green Dreams Ltd certified by Organic Food Federation of the UK to produce salad lettuce
- Vitacress Ltd certified by the Soil Association (UK) to produce spring onions, salads and baby carrots
- Kenya Nut Company certified to produce macadamia nuts and coffee

Conclusion

Organic production in Kenya is perceived as a separate entity from normal agriculture representing an alternative practice in farming. Organic farmers have isolated themselves to some extent and find it difficult to lobby for legislation and public goodwill. Even though the majority of organic producers are members of organizations such as the Fresh Produce Exporters Association of Kenya (FPEAK), Lake Naivasha Riparian Association (LNRA), Kenya Flower Council (KFC) to mention a few, they have not yet benefited from advocacy. The Agricultural Act does not recognize organic agricultural producers yet there is an increase in intolerance to Kenya fresh produce due to residue levels and non-compliance to the maximum residue limits set by the EU.

Establishing a national authority on organic production and marketing is of utmost importance as local certification would represent a step towards EU recognition of equivalence of national standards under Article 11(1). The first step is forming a secretariat with members from KIOF, KOFA, ABLH, KFC, FPEAK, MOARD, HCDA and the Kenya Plant Health Inspectorate Service. The secretariat will be mandated to police conversion, certification, production and sale of such produce in order to protect the bona fide producers and consumers. Such a secretariat will remove the complex and uncoordinated certification standards that preclude producers being able to find markets in countries because their current certification system is not respected. The benefits of organic agriculture to the farming community and country as a whole will remain under exploited unless the marketing and certification of organic produce is enhanced in the near future.

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Appendix

Sources of Information on Resource Management

The following contains a list of various organizations and internet websites with information on organic and natural resource management. Most of the contacts have been generated from participants at various events organized by FORMAT between 2000 and 2002. We encourage readers to contact these organizations and websites for additional information about their work.

Effective Micro-organisms Technologies (EM)-Kenya. P.O. Box 27 Embu; tele: 068-30950 <emtech@africaonline.co.ke>. Promotes the use of naturally occurring microorganisms in agriculture. EM-Kenya produces and distributes a wide range of products for application in agriculture.

Farmer's Journal. P.O. Box 44787, Nairobi, Kenya. Tele: 020-217965. A bimonthly magazine containing articles of interest to farmers in East Africa that frequently covers topics in organic resource management.

Forum for Organic Resource Management and Agricultural Technologies (FORMAT). P.O. Box 79, The Village Market 00621, Nairobi, Kenya. <formatkenya@yahoo.com>. Website: www.formatkenya.org. A forum for sharing of information, technologies and products by farmers, researchers and developmental workers involved in organic resource management and development and transfer of agricultural technologies in Kenya.

Hyacinth Crafts. P.O. Box 284, Kisumu, Kenya; tele. 035 44715 <hycraft2001@yahoo.com>. Promotes utilization of water hyacinth fibre for making handicrafts by communities around Lake Victoria. It also makes and markets an assortment of handicrafts and paper made using water hyacinth.

International Institute for Rural Reconstruction (IIRR). P.O. Box 66873 Nairobi, Kenya; tele. 4442610 <admin@iirr-Africa.org>. Conducts training and research in agriculture.

International Plant Genetic Resources Institute (IPGRI). P.O. Box 30677 Nairobi, Kenya <ipgri-kenya@cgiar.org>; Website: www.cgiar.org/ipgri. A CGIAR centre with responsibility toward conservation of plant genetic resources. It runs an African Leafy Vegetable Program aimed at improving the food security, nutritional status and livelihood of vulnerable groups in sub-Sahaharan Africa.

Kayole Environmental Management Association (KEMA). P.O. Box 20445 Nairobi <kemakenya@yahoo.com>. Involved in recycling and marketing of products processed from urban waste in Nairobi City. Its operations are concentrated in Kayole Estate, the most populous estate in Nairobi City.

Kenya Agricultural Research Institute (KARI). P.O. Box 57811, Nairobi, Kenya. The Kenyan government's lead agency in agricultural research. It provides publications, extension and training materials in agriculture and its research centres are spread throughout the country.

Kenya Association of Forest Users (KAFU) and **Forest Action Network (FAN)** P.O. Box 21428 Nairobi, Kenya; tele. 254-20-718398 Fax: 254-2-714406 <fankenya@africaonline.co.ke>. Promotes sustainable land and forest use.

Kenya Neem Development. P.O. Box 55126 Nairobi; <neemken@yahoo.com> tele. 0733-816980. Involved in processing, distribution and use of neem products for animal and human health.

Kisumu Innovation Centre Kenya (KICK) P.O. Box 284, Kisumu, Kenya <kick@swiftkisumu.com>. Promotes innovation and micro-enterprises applying organic resources such as water hyacinth.

Kenya Institute of Organic Farming (KIOF) P.O. Box 34972, Nairobi, Kenya; tele. 067 52466 <kiof@iconnect.co.ke>. KIOF is involved in training and extension of organic farming in Kenya. It has a training center and conducts regular courses on organic farming covering eastern and southern Africa.

Kenya Organic Farmers Association (KOFA). P.O. Box 509 Thika; tele. 067 72296. Promotes organic farming practices among its members and has published organic farming standards for smallhhold farmers in Kenya. KOFA is promoting group marketing of organic produce to external markets.

Kenya Resource Centre for Indigenous Knowledge (KENRIK). P.O. Box 40658, Nairobi, Kenya; tele. 020 3741673 <p.maundu@cgiar.org>. Located at the National Museums of Kenya and promotes cultivation and use of traditional green vegetables and indigenous plants in Kenya.

Manor House Agricultural Centre (MHAC). P.O. Box Private Bag, Kitale, Kenya <mhac@africaonline.co.ke>. Conducts training and extension of bio-intensive agriculture in western in Kenya. It has a training center and conducts regular courses on organic farming.

Ministry of Agriculture and Rural Development. P.O. Box 30028, Nairobi, Kenya. It is involved in training, extension, policy development and implementation in the agricultural sector.

Moi University, Soil Science Department. P.O. Box 1125 Eldoret, Kenya; tele. 053 63111. Conducts graduate training and research in soil science and involved in soil fertility research and replenishment in western Kenya.

Sagana Fish Research Station. P.O. Box 26 Sagana, Kenya; tele. 060 46041 <saganafish@africaonline.co.ke>. Conducts research on fish production and promotes use of organic fertilizers in fish farming.

Saroneem Biopesticides Ltd. P.O. Box 64373, Nairobi, Kenya; tele. 861680 ext. 4124 <drocco@icipe.org>. Involved in the processing, marketing and promotion of the neem tree and its products in agriculture.

Sustainable Agriculture Centre for Community Development (SACDEP). P.O. Box 1134, Thika, Kenya; tele. 067-30541. <sacdepkenya@iconnect.co.ke>. Involved in agricultural technology transfer, promotion of sustainable agriculture and community development projects with smallhold farmers in Central Kenya.

Sustainable Agriculture Centre for Research, Extension and Development in Africa (SACRED-Africa). P.O. Box 2248, Bungoma, Kenya; tele. 055-30788. <sacred@africaonline.co.ke>. Conducts on-farm adaptive research, farmer extension and development projects with smallhold farmers in western Kenya.

Tropical Soil Biology and Fertility (TSBF-CIAT). Programme of International Centre for Tropical Agriculture (CIAT). P.O. Box 30677, Nairobi, Kenya. Conducts research in soil biology and fertility in sub-Sahaharan Africa.

World Agroforestry Centre (formerly the International Centre for Research in Agroforestry). P.O. Box 30677, Nairobi, Kenya <icraf@cgiar.org> Website: www.cgiar.org/icraf. The World Agroforestry Centre conducts research in agroforestry through collaborative programs and partnerships locally and globally.

Internet Resources and Links

African Conservation Tillage (ACT-Network): www.fao.org/act-network

EcoNews Africa is a monthly magazine specializing in environment, trade and development issues published in Nairobi: **www.econewsafrica.org**

Funding opportunities in research and development, **www.rockfound.org** (The Rockefeller Foundation) and **www.fordfound.org** (Ford Foundation)

International Federation of Organic Agriculture Movements (IFOAM) www.ifoam.org

International fellowships for postgraduate training in East Africa by the **Inter-University Council of East Africa**, **www.iucea.org**

The Consultative Group of International Agricultural Research (CGIAR), a donor agency for leading international research centres, **www.cgiar.org**

A website on **Biotechnology, Breeding and Seed Systems for African Crops** featuring news and research findings on African crops, **www.africancrops.net**