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Environment, Population Growth and Productivity in Kenya: A Case Study of Machakos District

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This case-study of Machakos District, Kenya examines population growth, agricultural production and environmental conditions from 1930-90, and shows that population increase is compatible with environmental recovery, provided that market developments make farming profitable. Over this period, the value of output per person has increased threefold, while that per hectare has increased tenfold. Population growth with new market opportunities has stimulated investment and innovation, although some of the necessary capital has had to be generated from outside the agricultural sector. These findings are important since they are at odds with commonly-held views, which assume there has been little increase in agricultural productivity in Africa. Such views often consider population growth harmful to the environment, out migration to have a negative impact, and increased commercial production as damaging to food supplies. Development is seen to depend overwhelmingly on government initiatives and support, rather than farmers' own efforts.

The Machakos study shows the need for government policies which aid information flows and raise farm-gate prices, to encourage agricultural development and intensification. It also shows that population growth in agricultural areas renders change in farming and income systems inevitable since the old systems are not viable in the new circumstances. Farmers adapt to these pressures by innovation and investment and can develop new sustainable systems. Where there is a high degree of market integration, the

local economy can diversify and non-farm incomes expand. Government policies may either impede or assist these processes.

The Machakos study suggests that there may be two danger points in this process of agricultural intensification. The first comes with growing, but still low, population densities, when the incentives for investment in land improvements are weak due to lack of demand and poor transport facilities. At this point, degradation may occur. The second comes with very high population densities, when the marginal rate of return to increased inputs of labour and capital in relation to land may start to fall. However, this second point is reached far later than many people expect. We cannot be sure that it has been reached even in the areas of Machakos where densities are now over 400 people/km^2, since some of the difficulties now being encountered could be overcome under new policy conditions.

The farming environment

Machakos District, Kenya, is inhabited by Akamba people. Many observers in the 1930s and 1940s saw it as suffering from severe soil erosion and degradation of both cultivated and grazing lands, such that it could not support its 1948 average density of 67 people/ km^2. In 1990 soil erosion had decreased despite a more than fivefold increase in population, part of which has been accommodated by the spread of settlement into the more arid areas of the District.

The District can be divided into different agro-ecological zones (AEZ). For our analysis, we simplified the system devised by Jaetzold and Schmidt (1983) and divided the administrative units, known in Kenya as Locations, into three groups:

- mainly AEZ 2 and 3 - a small area of high-potential land occurring at the higher altitudes, covering about 8% of the District, most of it the marginal coffee zone.

- mainly AEZ 4 - the lower areas immediately bordering the central hills, much of it the 'badlands' of the 1940s. Jaetzold and Schmidt divide this into the maize-sunflower and marginal cotton-sorghum zones, although in fact in both the main crops are maize and pulses.

- mainly AEZ 5 and 6 - the southern and north western plains and most of the Yatta area east of the Athi river, described as the livestock-millet zone, although the main activities are maize, pulses and livestock.

Due to changes in boundaries and political conditions, the area available for agricultural activities has changed over time. Before independence, the Machakos Akamba were confined to the 'Reserve' lands, about 4,600 km^2 of which was inhabited in 1948. To this should be added Crown Land (i.e. government land not allocated for settlement) in an area known as the Yattas, where the Akamba were permitted to graze on payment of licence fees, and uninhabited bush within the Reserve, to make a total of about 7,000 km^2. Thereafter areas formerly used mainly as European ranch land and some additional Crown Land to the south of the Reserve were included in the District, bringing the total available land area up to 13,600 km^2.

The rainfall is characterized by great year to year variability. Rain falls in two main seasons termed the short (October to December) and long rains (March to May). Only a small proportion of the District can expect more than 250 mm in each rainy season - normally regarded as the absolute minimum for

the preferred staple food, maize. The farm environment is thus highly risky and maximizing the utility of rainfall is essential.

Sequences of three or more severe or moderate droughts cause a farming crisis, with food shortages and severe losses of livestock. Concern about erosion then becomes particularly acute since drought affects both the rapidity with which erosion takes place (by destroying protective vegetation), and the prominence of erosion features.

The environmental crisis and prescribed remedies

Erosion by storm water was the most conspicuous form of land degradation visible in the 1930s. The Akamba elders blamed environmental degradation on the government (for establishing the Reserve's boundaries) and on God (for the droughts) (KNA: Lambert, 1945). Confinement of the Akamba within the Reserve had prevented them from following their historic response to population increase or to drought: namely to set up new farms in uncultivated areas and take their herds further afield. With both these remedies forbidden, many men sought work outside the Reserve. Government policies of the time prevented them from responding fully to market opportunities; they were not allowed to compete with Europeans by growing coffee; the cattle trade was often restricted by quarantine regulations to protect European herds; and grains could not be sold out of the District without a permit.

The authorities blamed the environmental degradation on an irrational increase in herds, especially the 'ruin-bringing goat' (Maher, 1937); increase in human population; and cultivation without use of manure or other conservation methods. Among the remedies tried were efforts to restore the pastures by closing areas to herds, supplemented sometimes by ripping and resowing of grasses; the opening up of some additional grazing by building dams; and the clearance of the tsetse bush to create a new settlement for

farming under strict supervision and according to scientific rules (the Makueni settlement, 1946-58, described in Gichuki, 1991).

These programmes were expensive. During the 1930s and early 1940s they were largely funded out of normal revenues. From 1946 to 1962, Machakos also benefited from grants from the African Land Development Board's programme (ALDEV)[1] - totalling £1,414,000 (36% of all ALDEV expenditure). About 23% of this went to the Makueni settlement, which is now a prosperous farming area; however, since 1960 the Akamba have settled a much larger area with no special assistance. Another 23% of the ALDEV expenditure was for the Yatta Canal, opened in 1959 to provide water to the relief grazing area, while a further 23% went on soil and water conservation programmes. Many small dams constructed during this period remain useful. The bench terrace (in which soil is thrown up hill) although very labour-intensive, began to become common in the early 1950s, and has become a self-spreading innovation. The greatest expansion in terracing took place between 1961 and 1978 (Rostom and Mortimore, 1991) without compulsion and with almost no government aid (Table 1).

Compulsory government programmes were supplemented by efforts to create an incentive for more careful and profitable farming under the Swynnerton plan. Africans were permitted to grow small areas of coffee in the 1950s, with strict controls on farming methods, and in conjunction with terracing. A second incentive was the privatization of tenure. However, according to Akamba customary law, any land once cultivated was already private. Because of the strength of customary rights in land, the Swynnerton

[1] The ALDEV period was the only time that Machakos received more than its fair share of government resources. Later the EEC-funded Machakos Integrated Development Programme, 1978-88, provided some £10 per head (1990 values) over the ten years. During the period 1963-78 the semi-arid Districts were neglected compared with the higher-potential areas of Kenya.

provisions for registration of private tenure rights were less important in Machakos than in many other areas of Kenya.

Thomas (1974) found that by 1972 erosion was less connected with cultivation, but was still prominent on grazing land. His later observations in 1990 led him to conclude that rates of erosion have been considerably reduced, due to terracing on cropped land and careful management of grazing. Currently, many of the main causes of erosion are non-agricultural: roads, communal watering points, sand extraction points (Thomas, 1991).

Farah (1991) concluded that in the AEZ 5 and 6 lands settled in the late 1960s and 1970s, there was no evidence of irreversible grazing-induced degradation. Rather, there was some increase in woody types probably due to lack of regular burning, a practice discouraged by the government. In AEZ 4, a more intensive management system has developed, from which farmers gain charcoal and timber, goats keep the bush down, while desirable trees are protected (Mortimore, 1992). As regards soil fertility, continuous farming without any replacement of nutrients is no longer the norm in Machakos. However, it would be difficult to quantify how much of the agricultural land is manured or otherwise fertilized, and to what effect.

Population growth and changes in production

Human population increased by about 2.5% per annum up to 1948, this growth accelerating to 3.76% in 1969-79. Since 1979, this growth rate has fallen to around 3% a year, and the total population of Machakos stood at about 1.4 million in 1989. Growth has been due to natural increase and the population remains predominantly Akamba. The few in-migrants are mainly living in the towns, and for the period up to 1979 there was more out-migration than in-migration.

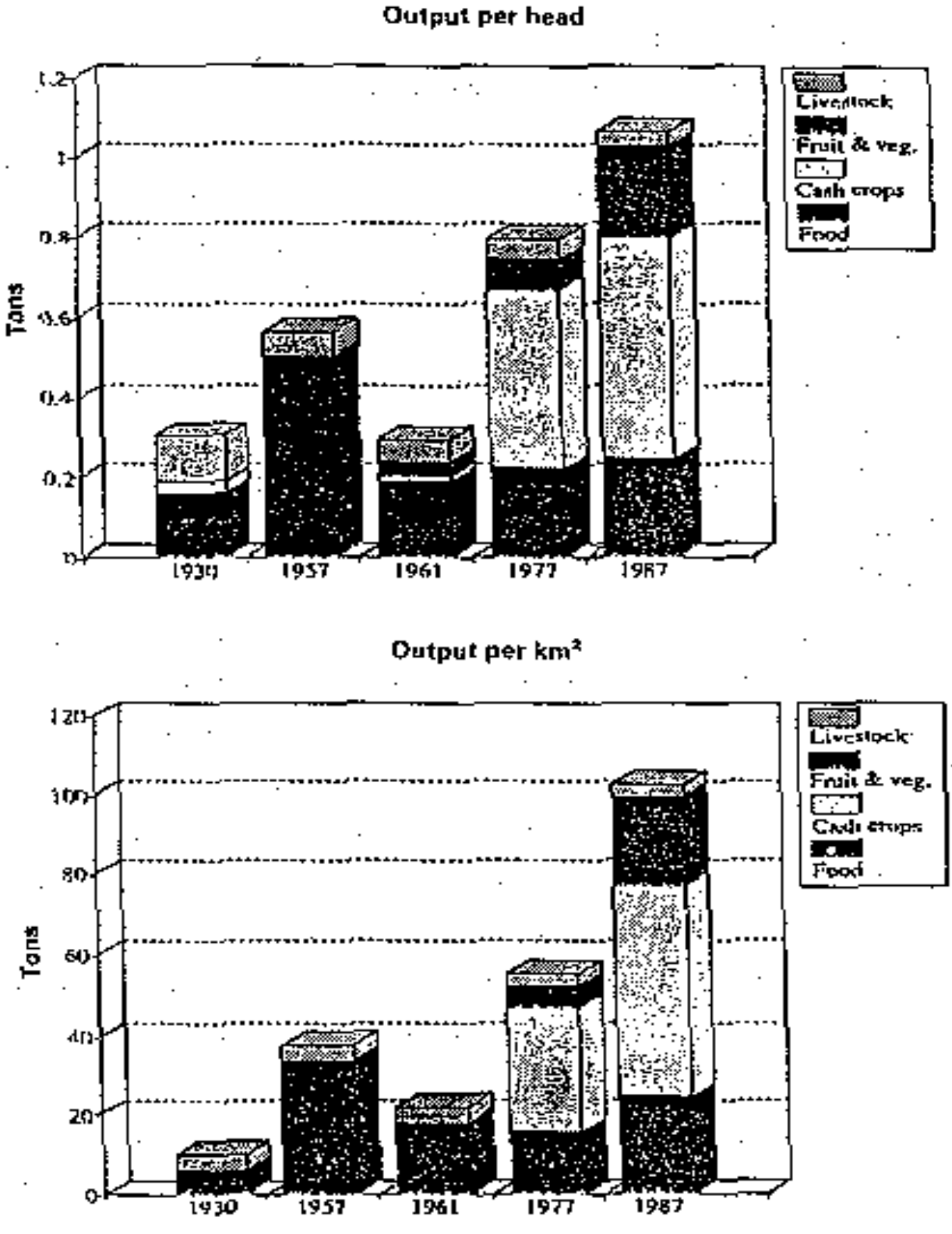
Population densities were already over 100/km² in 1948 in the highlands. As noted earlier, after 1960 there was a surge into lands previously forbidden for settlement. This large scale movement was entirely unofficial and by 1979 there had ceased to be any unclaimed land. Temporary out-migration for work continued after 1960, and began to include women as well as men. However, its importance seems to have declined, due to increased competition for jobs in other parts of Kenya (Tiffen, 1991).

Figure 1 shows estimated production per head and per hectare in 1930 and 1957, taken from the records of District and Agricultural Officers. All crops and livestock output have been converted to their buying power in terms of maize, at 1957 prices. The estimates are crude and are shown in graphical form to emphasise orders of magnitude, rather than exact figures. These figures show an increase in output per head between 1930 and 1960 from the equivalent of about 250 kg to about 400 kg maize. The main cash[2] crops shown in the graph are cotton and coffee, especially the latter, although they include sugar (used for beer) in 1930.

The steep growth of productivity in Machakos occurred between 1960 and 1980, at a time when it enjoyed no special government programmes, and when most government agricultural resources were concentrated on the Kenya's higher potential districts. During this period the average annual population increase was about 3.4%, varying from about 2% in the older settled areas to very high rates in the lower potential AEZ 5 and 6 which had become open for settlement. The creation of new farms in AEZ 5 and 6 was accompanied by predictions of environmental and economic disaster (Wisner, 1977). However, calculations based on the Annual Reports of the District Agricultural Officer in

[2] We are using cash crops as a term for crops grown only for sale. Machakos farmers have always also derived cash from livestock, and from food and horticultural crops which they also consume.

FIGURE 1
Output per head and per km²: maize equivalent, 1957 prices



two average years (each with one good and one bad season) show that production per head, and output per km^2, had risen substantially by 1977 and 1987 (Figure 1)[3].

Between the 1979 and the 1989 censuses overall population growth rates appear to have fallen to about 3% per annum. While output per hectare continued to grow, it has fallen behind population growth rates, since there is no new land to be occupied. This suggests that in some areas the point of diminishing returns has been reached.

Population growth exceeding 3% per annum has been absorbed since the 1950s in Machakos, by a combination of developing new farmland, capitalizing older farms, and diversifying income sources into the non-farm sector. The most acute environmental degradation occurred in the 1930s and 1940s at much lower population densities than at present, but this degradation has been reversed by human endeavour and by investment and employment diversification stimulated and made possible by the market.

However, due to its very erratic climate, the District is still subject to food shortage and difficulty in financing food purchase whenever there is a sequence of bad seasons, such as occurred in 1983-4. The variability of the rainfall suggests such difficulties will continue to occur from time to time.

Land investment

The process of agricultural intensification in Machakos can be illustrated by examining the ratio of arable to non-cultivated areas, and the increase in terracing. These were surveyed in a sample of five areas covered by aerial photographs taken in 1948, 1960-61, and 1978.

[3] The figures used as the foundation for these calculations are tabulated in Ackello-Ogutu (1991) and Mbogoh (1991). Output per km^2 is based on 7,000 km^2 up to 1963, and 13,600 km^2 thereafter. The latter includes a substantially higher proportion of AEZ 5 and 6 land.

Table 1: Cultivated and Terraced Land

Location	Order of Settlement	AEZ	Percentage under cultivation			Percentage of cultivated land terraced		
			1948	1961	1978	1948	1961	1978
Mbiuni	1	2/3	35	35	81	70	76	100
Kalama	2	2/3	14	14	54	62	45	100
Masii	3	4	23	28	51	13	29	100
Makueni	4	4/5	1	8	30	*	1	100
Ngwata	5	5	0	0	20	0	0	27
Overall	-	-	16	18	51	52	50	96

* Only 160 ha cultivated, about half terraced.

Source: Rostom and Mortimore, 1991.

Table 1 shows that land-use intensity (i.e, proportion cultivated) varied according to two major factors: a) by geographical area, with the highest intensity in the long settled highlands, and b) by time, the proportion of land terraced increasing over time, with increases in population density. The most rapid increase in cultivated area has been since 1961, with cultivation spreading and intensifying in newly settled areas.

For the period after 1978, two surveys carried out by Ecosystems in 1981 and 1985, provide no evidence of a large-scale extension of cultivated area. Rather, there was an increase in field division, and a decrease in average field size, confirming that the period of new land settlement had come to an end, and

that heirs were having to divide existing farms. Soil and water conservation structures have been the most important investments on arable land. By 1978 all arable land was terraced in areas where settlement had started in the 1950s or earlier; terracing had reached 27% in the area settled from the late 1960s.

Changes in farming and income systems

The first detailed descriptions of peasant farming in Machakos stem from the 1960s (Heyer, 1966: Owako, 1969). For earlier periods we must rely on oral recollections, and brief mentions in administrative reports. An assessment of long term changes in farm incomes is hampered by the lack of economic evidence. Very few of the farm surveys carried out in the 1960s, 1970s and 1980s refer to capital assets, and where they do, the inventory is always incomplete. Yet the farming systems found today are based on intensive investment of capital and labour in terracing, hedges, trees, equipment, improved livestock, etc.

The scanty written evidence suggests that before the 1950s farming systems were relatively similar in AEZ 3 and 4, the two main inhabited areas, though farms were smaller in the former. Basically, people grew food crops, and relied on livestock for milk, meat and a certain amount of cash. In the northern hills, road connections with Nairobi were sufficiently good to have encouraged some crop production for the market. This is shown in Table 2, which summarizes information from village leaders about main farm activities producing cash in 1945, 1960 and 1990. Before the 1950s, society was also relatively undifferentiated in its occupations. Most people were farmers, *although a few shopkeepers and traders had established themselves*, often with the help of savings from jobs outside the District. In 1960, some 80% of income came from farming, and was mainly in kind.

Table 2: Main Farm Cash Income Sources, 1945-90

		1945	1960	1990
Kirigundo (AEZ 3)		Wheat, grams, coriander, sugar, bananas, other food crops, cattle, milk	Fruit, vegetables, coffee	Coffee, French beans
Mbooni (AEZ 3)	(men)	*Livestock, sugar, bananas*	Sugar, English potatoes, wattle, livestock	Coffee, vegetables, trees
	(women)	Livestock, food crops	Food crops, livestock	Coffee, vegetables, handicrafts
Masii (AEZ 4)	(men)	Cattle, millet	Livestock, millet beans, maize, livestock	Cotton, fruits, pawpaws, tomatoes,
	(women)	Ghee, cattle	Goats and cattle	Peas, beans, maize, mangoes
Makueni *(AEZ 4 & 5)*		—	Goats, peas, beans, maize, grams	Fruits, cotton
Ngwata (AEZ 5 & 6)	(men)	—	(1965-70) Charcoal, honey, ivory	Maize, beans, livestock, pigeon peas, cotton, grains
	(women)	—	Remittances and help from home	Grains, sorghum, cowpeas, charcoal, livestock

Source: Interviews with village leaders, 1990

Table 3 Farm and non-farm income estimates (Percentages)

		Farm income	Non-farm business	Wages	Remittances
1960[1]		80	2[2]	6[3]	11[3]
1974-5	Coffee[4]	51	5	32	12
	Cotton[5]	26	25	31	32
1981-2		51	17	24[7]	9[7]

Notes and Sources.

1. Peberdy 1961, Table VI (Calculation of Total District Income plus subsistence production). 1960 was a bad year, but slightly better than 1974-5.
2. Refers to carvings only.
3. Wages: earned in District. Remittances: 20% of wages earned outside District.
4. Integrated Rural Survey, 1974-5, Table 8.7. Incomes for Coffee Zone East of Rift. (Includes Machakos AEZ 2 and 3). Total household income: Ksh 4,087.
5. As above. Incomes for Lower Cotton East of Rift. (Includes Machakos AEZ 4,5,6). Total household income: Ksh 2,479.
6. Economic Survey, 1988, Table 3.12. Machakos District. Total household income: Ksh 10,368. 1981 had a severe drought in the short rains, affecting the early 1982 harvest, but good long rains.
7. Wages - no information on whether internal or external. No 'Remittance' heading. Remaining heading was 'Other sources'.

During the 1950s fruit and vegetable production expanded in the hill areas nearest to urban markets, and coffee was introduced. This was particularly marked in the Kangundo area, where an improved road to Nairobi encouraged the sale of crops. In the 1960s, farm size in AEZ 2 and 3 averaged only about

3 hectares, some 80% of which was arable. Only a few livestock were kept, for milk, draught and manure. By 1990 farmers in some hill areas were stall-feeding one or two grade cattle for intensive milk production. The farms had become so small that the majority no longer kept draught oxen. A large part of the farm was still under the staple foods of maize and beans. However, coffee growing and horticulture had expanded and income sources had become more diversified. For example, in 1979, amongst a sample of 200 women with pre-school children in one AEZ 3 area, only 21% had husbands who were farmers without another occupation (Rabeneck, 1982). The large majority were shopkeepers, craftsmen, small business owners, labourers or in clerical work, as well as being part-time farmers.

In 1990, the farming system in AEZ 4 was still dominated by maize and bean production. However, since the 1980s, fruit production and food crops have largely replaced livestock as the main cash earners. Draught oxen are now a key element in a much more productive and organized farming system. Once, crop production in the long rains was characterized by late-sown crops poked in amongst the standing crop from the earlier short rains, with effort intensifying only if the short rains had failed (Porter, 1965, Owako, 1969). By the 1970s, both long and short rainy seasons were fully utilized (for details see Tiffen, 1992).

In 1990, village leaders in AEZ 4 agreed that the effect of low rainfall was no longer so drastic as before. This is a result of intensive investment in bench terracing and cut off drains which collect water and channel it to the terrace system.

Farmers in the drier, recently settled areas, initially cleared the bush to establish customary land rights to a large farm. Subsequently, much land has been allowed to revert to private grazing. Farms in AEZ 5 and 6 are very similar to those in AEZ 4, but with greater emphasis on livestock. From the

late 1980s, there has been increased terracing of these areas, often assisted by non-governmental organizations.

Food production

At the end of the 1980s, food crops still occupied some 85% of cultivated land. Output of grains and pulses has kept pace with population increase. Food imports and famine relief averaged 17 kg per head per annum from 1942 to 1962 but had fallen to 7.6 kg over the period 1974-85, indicating some improvement in average food availability per person. Evidence would suggest that average maize yields have also risen from 0.5 tons/ha in the 1955-65 period to an average of 0.85 tons/ha in 1974-88. This overall increase has not been due to fertilizer, which is still little used (Mbogoh, 1991) and is despite the much increased utilization of AEZ 5 and 6 land, which by 1979 contained 36% of the population. Rather, higher yields are due to use of drought resistant varieties, more manuring, better water conservation and weed control.

Horticultural and cash crop production

Horticultural and cash crop production in the 1980s have increased since the 1950s. The census of 1960/61 records only 500 ha of coffee, and about 4,400 ha under fruit and vegetables, some of which were mixed with other crops. By 1977 the area under coffee had expanded to 7,100 ha, and this had doubled to 14,800 ha by 1988. The area under fruit expanded to 5,000 ha in 1977, and 8,300 ha in 1988. Land cultivated with vegetables was estimated at 600 ha in 1977 and 5,900 ha in 1988.

However, because of the unusually high coffee price in the 1977 coffee boom, real incomes per head were higher in 1977 than in 1987. In the 1980s people partially compensated for the fall in the coffee price by a massive switch into fruit and vegetables but, once planted, coffee cannot legally be uprooted.

The other factor depressing incomes was a decline in areas planted to cotton, due low prices and late payments.

Livestock production

The substantial increase in crop output from 1977 to 1987 has not been matched by a decline in livestock output, although there has been some reduction. In the period 1930-60 cattle numbers were estimated at 200-250,000 in the Reserve, with another 40-50,000 on European ranches. Cattle numbers show great year to year variation. In 1977, 491,000 cattle were reported in the area, an exceptionally high figure which had fallen to 388,000 by 1987. By the end of the 1980s, some 10-12% of cattle numbers were made up of the more productive 'grade' cattle. Goat and sheep numbers show even more annual variation.

Cattle numbers in the 1980s were substantially higher than in the period before 1960. The increased ability to support cattle is due to changes in management systems, particularly in the small farm sector. With no more communal grazing land left, farmers must rely either on carefully managed private grazing land and crop residues, or on zero grazing systems. There are also better animal health services. In addition,on small mixed farms recovery of livestock numbers and productivity after drought is faster than in neighbouring ranch areas (for further details see Ackello-Ogutu, 1991; Mortimore and Wellard, 1991).

Non-farm income

As in many areas of Kenya, most families have at least one person with a non-farm job or business, either inside or outside the District, while the number relying on temporary migrant labour appears to have fallen. In addition,

income is earned from crafts and sales of products such as charcoal, honey and chickens.

The proportion of total income coming from farming in a given year depends on rainfall conditions. There have been two attempts to measure rural incomes on a national scale. One was in 1974-5, when incomes throughout the region were much affected by drought. The second was in 1981-2, a more average year (one severe drought, one good rains). The results of these two surveys are shown in Table 2, from which it will be seen that farm income in 1981-2 was about 50% of total income. In 1974-5, despite the drought, it was 50% of total income in the marginal coffee zone, where farm products consumed equalled 76% of total farm income. By contrast, in what were termed the cotton zones (where most production is in fact grains and pulses), farm products consumed were 135% of farm income, due to drawing down of stocks of grain and livestock, and farm income was only 26% of total income. While comparison with earlier periods is problematic, because of different methods of calculation, figures from 1960 suggest that the farm provided 80% of total income, of which 85% was subsistence crops (Peberdy, 1961). Although non-farm incomes were probably underestimated, this sector was certainly smaller than in 1987 (about 1,600 licensed shops in 1957 compared with 8,000 in 1987 (Mbula Bahemuka and Tiffen 1992)). In the 1950s non-farm income came mainly from externally generated wages (Peberdy, 1961), and contemporary reports suggest that as many as half the adult men in some areas were absent.

Specialization and growth in high value crops have generated a larger number of local non-farm jobs than when the economy was more subsistence-orientated. This process has been assisted by improvements in roads, and electrification.

The economics of recovery

Thus, behind the physical recovery of the land lies a story of increasing yields and investment per hectare, as demonstrated also by rising land values. Land prices have risen from the equivalent in the 1920s of one goat per acre (worth about Ksh 350 today), to Ksh 40,000 without trees and Ksh 80,000 with trees in one AEZ 3 village in 1990.

The increase in the value of output per hectare has taken place as a result of several factors:

- increased and more efficient use of the second, long rainy season. Almost all cultivated land is now double cropped, rains permitting;
- more careful management of rainfall and soil moisture;
- greater integration of livestock and crops, utilizing crop residues for feed and manure for crops;
- investment in fewer but higher quality and healthier livestock per household;
- a switch of some land into higher value crops, such as coffee, fruit trees and vegetables;
- planting and/or protection of trees in grazing lands, croplands and hedgerows, to provide fuel, timber and fodder.

These changes in production systems required investment, in capital and labour, at the farm level. At the community level it also required a variety of services

and complementary investments from traders, such as farm inputs, and consumption goods, as well as the collection of farm produce for sale.

When degradation was at its worst, the population density of Machakos District was around 50/km^2. Roads were few and transport expensive, so that in most of the District the only marketable commodity was livestock. In such a situation there is neither an incentive nor the means to invest. Improvements to degraded pasture land are high in cost relative to the expected benefits, especially where unimproved stock are very vulnerable to disease and drought.

In a semi arid, unpredictable climate, it may be very difficult to raise the capital needed for investment in agriculture. The most common source of farm capital has been off-farm work, although livestock sales also helped. The first priority for investment has often been setting up a non-farm business (transport, a shop, etc.), followed or accompanied by investment in schooling for the children. If any investment were made in the farm at this stage, the money went into buying a plough or planting coffee trees. The investment in schooling was expected to secure a well-paid job for the child, who in due course provided capital to develop the farm. In both the newly settled and the old-established farming areas, much has been achieved by investment of family labour as well as paid and group labour. At the same time, considerable community investment has occurred, through self-help activities, for dips, schools, feeder roads, etc.. Where once cattle had been the only possible investment and store of wealth, there are now several. In the northern hills they say 'Now, coffee is the cow'. Down in the lower potential areas livestock are still valued: 'A family with cattle is the same as a family with a graduate'.

While there was intense government activity in the ALDEV period, from 1946-62, in soil and water conservation the most productive external intervention has been on the advisory side, and through the provision of tools to groups. For example, tools were provided in the 1940s and 1950s, and

during the late 1970s and the 1980s by both government and NGO programmes to groups working on a self-help basis. However, many farmers also reported that they had built their terraces without outside help, using labour which they had hired.

Soil and water conservation

The authorities always put the emphasis on soil conservation rather than water conservation, although some agricultural officers realized, and taught, that the bench terrace and cut-off also conserved water. Farmers preferred these bench terraces to the narrow base terrace because they saved water and land, and were easier to maintain, although they took more labour to construct. The bench terrace was tried out in the 1930s but was not widely adopted until the 1950s, but by 1957 bench terrace construction had surpassed the narrow base terrace (Peberdy, 1961). The history of soil and water conservation shows the importance of offering farmers a range of options if an introduced technology is to gain wide acceptance (Gichuki 1991).

The spread of production technologies

Many other new technologies were introduced in this period (see Mortimore and Wellard, 1991). Innovations came from multiple sources, including government research, farmers' experiments, and through traders (cf. Biggs, 1989).

The plough at first enabled the extension of cultivated areas for market production. It also enabled water-saving husbandry - ploughing on contour, and dry planting. First weeding by plough reinforces ridges as well as saving labour. The plough was adopted without extension effort, through purchases from traders. Farmers make skilful use of a light mould-board plough drawn by two bulls or oxen, and have not been interested in the much more expensive

tool bar which the Machakos Integrated Development Programme tried to popularize in the early 1980s.

Katumani Composite B maize was bred by government researchers in the early 1960s as a short-season, drought-resistant variety. It has been widely adopted, but farmers also cross breed it with local varieties, or plant both Katumani and a local variety.

Coffee was important in making terracing profitable in hill areas. It brought in much more money and provided the means to invest in other farm inputs as well as non-farm businesses. It has also created employment. Although introduced under tight controls, it spread rapidly in the 1970s when controls were relaxed and prices high.

Fruit and vegetables were introduced by government, missions and traders. They have spread from farmer to farmer, or from trader to farmer, rather than via the formal extension system. Oranges and pawpaws are now major income earners in AEZ 4, and have replaced cotton, despite the latter being strongly promoted by government. Crops such as French beans for the European markets supplement coffee cultivation as a source of income for farmers in AEZ 2 and 3.

Changes in institutions

During the sixty years under review, Akamba society has changed in ways which have facilitated the adoption of new technologies and the accumulation of capital (Mbula Bahemuka and Tiffen, 1992). Four elements should be highlighted. Firstly, there are now far more channels for information flows, whether through formal services such as education and extension, or through informal means such as travel, and meetings. Secondly, a far wider group of people are now involved in decision-making at village level, such as women, and the educated young men, as well as older men. In 1930 leadership was

mainly in the hands of the older patriarchs. The emergence of women as significant economic agents has been partly due to male out-migration.

Thirdly, self-help groups at the local level, which derive from an older tradition of mutual help, have developed new features, including detailed project plans, elected leaders, and the ability to raise money as well as pool labour. Such groups have been encouraged by a community development programme which originated in the 1950s and continues today. The groups not only pool local resources, but have learnt how to gain access to capital and expertise from national and international sources, through links to the political system, the churches and NGOs. Fourthly, there is the family, which remains a very important structure through which labour and other resources can be mobilised. For example, capital for farming improvements continues to come mainly from relatives.

Conclusion

Continuing population growth, in association with market development, has generated new technologies which have supported both increased productivity and improved conservation of land and water resources[4]. Increased involvement in the market has not only produced higher incomes from farming, but also generated many new non-farm jobs. While some parts of Machakos District are now showing some signs of decreasing returns to capital and labour, there may still be some scope for greater agricultural intensification and increased diversity of income sources. This would require policies to be followed which

[4] The Machakos case thus illustrates the hypothesis that population growth drives indigenous technological change in agriculture (Boserup, 1965). We differ from Boserup mainly by a greater emphasis on the importance of market development, and by accepting that technological change has several sources. For a discussion, see Tiffen and Mortimore, Journal of International Development, forthcoming. The authors are now working with Francis Gichuki on a book which will develop the many lessons of the Machakos case.

further develop trade, transport, education and infrastructure. Higher farm-gate prices are probably the single most important action required from governments to encourage soil and water conservation, and maintain the agricultural resource base. At the same time, removal of restrictions (such as the ban on uprooting coffee) would allow farmers to respond to changing economic conditions. Recent reforms to marketing in Kenya provide some grounds for hope; restrictions on trade in maize have been abandoned, and attempts are being made to reform the marketing boards. If followed through, these should help to raise farm-gate prices, incomes and incentives. Investment in roads is another means of improving farm-gate prices, while rural electrification would take the pressure off the diminishing land resource, by encouraging local industry.

Agricultural extension, research, education, community development and the provision of infrastructure, have enabled people to take advantage of new opportunities and to adapt to a rapidly changing situation. Over the period 1978-88, Machakos also benefited from another special programme, the EEC-funded Machakos Integrated Development Programme. However, this provided only some £10 per head (at 1990 values) over the ten years, similar to the average for donor-funded programmes in arid and semi-arid areas elsewhere. These programmes have had a disappointing record, and the resources they provided have generally been captured for 'normal' government programmes (Adams, 1990).

The experience of Machakos would suggest that there is little alternative to good governance, to provide an environment which enables people to struggle, more or less successfully, with difficulties imposed by nature and by their incorporation into the world economy.

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