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The economic linkages between rural poverty and land degradation: some evidence from Africa

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Abstract

This paper focuses on the potential role of policy in influencing the poverty and land degradation problems facing Africa. This is done through exploring a few case studies, chosen from a broad spectrum of African countries — Sudan, Malawi, Nigeria, Ghana and Kenya. The first case study examines the comparative returns to the gum arabic agroforestry system cultivated by poor farmers in Northern Sudan, and the role of policies in influencing these returns. The second explores how erratic agricultural pricing policies in Malawi during the 1980s may have distorted the incentives of poor smallholders to adopt less-erosive crops in their farming systems. The third case study illustrates how inappropriate policies and investments can cause displacement of poorer rural groups from their traditional farming and grazing lands, by examining the loss of a major floodplain due to dam building in northern Nigeria. The final two case studies are concerned with policy 'lessons learned'. The first looks at the impact of a macro-economic adjustment policy — in this case trade liberalization — on farmers' decisions to expand cultivated area rather than intensify crop production in western Ghana. The final case study examines the role of policy in land management success story in Africa, the Machakos District, Kenya, and explores the critical question of whether this success can be replicated elsewhere in Africa. These case studies serve two important functions. First, they demonstrate how policy analysis can be effective in highlighting key dimensions of the poverty–environment linkages underlying land degradation. Second, they illustrate how both 'good' and 'bad' policies can affect the economic incentives determining poor rural household's decisions to conserve or degrade their land.

Keywords: Africa; Economic policies; Land degradation; Rural poverty

1. Introduction

In recent years, land use in Africa has been characterized by a significant amount of land degradation and conversion. Moreover, these two processes are clearly related (Barbier, 1999). Overgrazing and agricultural activities are major causes of land degradation across Africa (Oldeman et al., 1990; WRI, 1992). Many poor African pastoralists and farming households respond to declining land productivity by abandoning their existing degraded pasture and cropland, and moving to new lands for grazing and cultivation. Even if rural households choose to stay on degraded land, its declining productivity will be unable to support growing rural populations. Thus, some households will be forced to abandon existing agricultural areas in search of new land. However, without additional investments in soil conservation, this process will repeat itself. Eventually, overgrazing and cultivation will lead to land degradation, and the search for new pasture and cropland will begin again.

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One reason for this ‘cumulative causation’ link between land degradation and conversion in Africa is that agricultural cultivation across the region is not highly productive. Yields for African countries are well below the global average, and are almost one-third of the yield levels of Asia and half that of South America (FAO, 1997). Moreover, cereal productivity in Africa has remained stagnant at 1980 levels, just over 1200 kg/ha. The poor productivity of African agriculture is in turn a reflection of its comparatively low input use. Very little of cropland area — only around 6% of the total — is irrigated. Fertilizer use is also sparse, averaging only around 18 kg/ha of cropland. Whereas average fertilizer usage is much higher in other developing regions, and has increased since the early 1980s, the rate of application on Africa’s cropland has hardly changed. As pointed out by Reardon et al. (2000) the low use of fertilizer across Africa is a major cause of concern, both from the food production and environmental perspective. In particular, the authors argue that ‘capital deficient, unsustainable intensification widespread in Africa today is a major force behind farmland degradation and thus productivity loss’. As a result, African agriculture tends to be mainly extensive in its use of land, and as land that is already low in productivity becomes degraded, it is cheaper to bring additional land into production rather than invest in maintaining the long-term productivity of existing cultivated land.

However, there is nothing ‘inevitable’ about these ‘cumulative’ causation linkages between land degradation and conversion faced by poor rural households in Africa. Many of these linkages, and the incentives for rural smallholders to counteract them, are influenced by prevailing agricultural and economic policies. In many instances, such policies actually reinforce these linkages rather than encourage smallholders to invest in improved land management and agricultural intensification. This does not have to be the case. Moreover, it also suggests that the design of better economic and agricultural policies could go a long way to ameliorating some of the worst aspects of land degradation and conversion in Africa, thus also improving the economic livelihoods of the rural poor.

The following paper focuses on the potential role of policy in influencing the poverty and land degradation problems facing Africa. This is done through exploring a few case studies, chosen from a broad spectrum of African countries. These case studies serve two important functions. First, they demonstrate how policy analysis can be effective in highlighting the key dimensions of the poverty–environment linkages underlying land degradation. Second, they illustrate how both ‘good’ and ‘bad’ policies can affect the economic incentives determining poor rural households’ decisions to conserve or degrade their land.

The first two case studies are concerned directly with the incentives for smallholders to invest in improved land management. The first case study examines the comparative returns to the gum arabic agroforestry system cultivated by poor farmers in northern Sudan, and the role of policies in influencing these returns. The second explores how erratic agricultural pricing policies in Malawi during the 1980s may have distorted the incentives of poor smallholders to adopt less-erosive crops in their farming systems. The third case study illustrates how inappropriate policies and investments can cause displacement of poorer rural groups from their traditional farming and grazing lands, by examining the loss of a major floodplain due to dam building in northern Nigeria. The final two case studies are concerned with policy ‘lessons learned’. The first looks at the impact of a macro-economic adjustment policy — in this case trade liberalization — on farmers’ decisions to expand cultivated area rather than intensify crop production in western Ghana. The final case study examines the role of policy in land management success story in Africa, the Machakos District, Kenya, and explores the critical question of whether this success can be replicated elsewhere in Africa.

2. Gum arabic versus annual crops, northern Sudan

This case study is based on Barbier (1992) and Pearce et al. (1990, Chapter 6). The gum arabic tree (*Acacia senegal*) is a naturally occurring species in the Sudano-Sahelian region that serves a variety of valuable economic and ecological functions. The gum produced by the tree — the ‘gum arabic’ — is widely sought after in importing countries for use as an emulsifier in confectionery and beverages, photography, pharmaceuticals and other manufacturing industries. In addition, the *A. senegal* tree provides fodder for livestock, fuelwood and shade. There are also numerous indirect benefits associated with this tree, i.e. its extensive lateral root system reduces soil erosion and runoff, as a leguminous tree it fixes nitrogen which encourages grassy growth for livestock grazing, it serves as a windbreak and *A. senegal* is important in dune fixation. For these reasons, the tree is the preferred species in bush-fallow rotation and intercropping farming systems prevalent in the arid west of Sudan. On a larger scale, across the Sudano-Sahelian region, the gum arabic 'belt' acts as a buffer against desertification.

The choice by farmers in Sudan to incorporate gum arabic trees in their farming systems will depend on whether the above benefits from a gum arabic-based system exceed those of alternative systems. The potentially high financial rate of return to a gum arabic-based farming system coupled with its important environmental benefits would seem to imply that such a system would be ideal for combating desert encroachment and rehabilitating the gum belt of Sudan. However, in recent decades, distortionary government exchange rate, export and pricing policies have meant that the real producer price of gum arabic in Sudan has fluctuated considerably, as has the relative price of gum to its competitor cash crops, sesame (*Sesamum orientale*) and groundnuts (*Arachis hypogaea*), and even food crops, such as sorghum (*Sorghum bicolor*) and millet (*Pennisetum americanum*). Farmers' share of the export value of gum also remains low, which has been one reason for the recent increase in smuggling of gum to neighbouring countries.

An economic analysis was conducted of six representative cropping systems containing gum arabic cultivation in Sudan (Barbier, 1992). The results are indicated in Table 1. Although the analysis shows that all six systems are economically profitable, the relative profitability of gum compared to other crops in each system is generally lower, except in the Tendelti system of the White Nile where field crop damage occurs frequently. In most systems, there are initial losses due to the need to establish gum gardens before they begin producing. This would suggest that maintaining the real producer price of gum by removing distortions in the market, as was assumed in the analysis, is a necessary economic incentive to encourage gum cultivation.

The analysis in Table 1 suggests that it may be more economically profitable to replace the gum arabic component in each of the six systems with annual crops. However, despite the lower relative returns to cultivating gum arabic, there are several reasons why converting land under *A. Senegal* to cultivating annual crops may not be desirable: (1) Some land under *A. senegal* may not be suitable for growing annual crops, resulting in very low and fluctuating yields. (2) Fallowing land may be important to maintain its fertility; gum arabic is the ideal cash crop for this purpose. (3) The environmental benefits of gum arabic trees (e.g. control of erosion/runoff, wind breaks, dune fixation, nitrogen fixation) were not included in the analysis, and these may be significant in maintaining the yields of field crops within the farming systems. (4) The role of the gum belt in controlling desertification certainly

Table 1
Economic analysis of six cropping systems, Sudan (1989/1990 Sudanese Pounds per Feddan, 10% discount rate) from Barbier (1992)

Province[a]	*A. Senegal*[b]	Sorghum	Millet	Groundnuts	Sesame	All crops
BN	2989.57	4606.83	2931.58	–	–	10527.98
WN	3923.82	−432.99	486.30	5330.92	8605.12	17913.17
NK	1471.36	–	2091.77	–	6020.94	9584.07
SK	882.99	1644.44	–	13109.44	13776.95	29413.82
ND	1240.87	–	2363.89	9687.69	–	13292.45
SD	1884.02	3830.80	3775.60	9715.61	–	19206.03
All	2065.44	2412.27	2392.83	9460.92	9467.67	16656.25

[a] BN: Blue Nile Province, clay soils, largeholder; WN: White Nile Province, sandy soils, smallholder; NK: North Kordofan Province, sandy soils, smallholder; SK: South Kordofan Province, clay soils, largeholder; ND: North Darfur Province, sandy soils, smallholder; SD: South Darfur Province, sandy soils, smallholder; All: average of all six systems.

[b] Total NPV from gum, fuelwood and fodder, except for Blue Nile and South Kordofan (gum only).

is significant in supporting and protecting farming systems in the region, and although this collective benefit cannot be captured in an analysis of individual systems, traditional farming communities in the gum belt region are very much aware of this benefit. (5) Risk-averse farmers may desire some of their land being held under gum cultivation, because the returns to gum — although lower than the maximum expected returns from the cash crops — may be less variable under stressful environmental and climatic conditions. (6) Gum cultivation provides cash income to farmers outside of the growing season for cash crops.

Thus, a full economic assessment of the wider environmental benefits of gum arabic systems, and not just the returns to marketed gum, would perhaps reveal the true economic value of these systems compared to annual crops. Nevertheless, from the farmers' perspective, maintaining the real producer price for gum arabic over the long term is crucial to ensuring that farmers have appropriate incentives to rehabilitate and cultivate gum gardens as part of their cropping systems. Over the long term, maintaining the real producer price is essential for farmers to undertake the important investment decisions necessary to replant stands; otherwise, other profitable uses of the land, such as for groundnuts and sesame cultivation, may appear more attractive. Distortionary economic policies in Sudan, such as an overvalued exchange rate, prohibitively high export taxes on gum arabic and monopolistic marketing practices, that undermine the comparative returns to gum arabic production by farmers are detrimental to their livelihoods and to controlling land degradation and desertification in the semiarid regions of the country. Moreover, the domestic resource costs to producing gum arabic in Sudan are extremely low, ranging from 0.52 using the actual exchange rate, and falling to 0.24 using the shadow exchange rate (Barbier, 1992). This suggests that Sudan has a comparative advantage in producing and exporting gum arabic, which is not surprising given that *A. senegal* is native to northern Sudan and has been cultivated by farmers there for hundreds of years. Thus, both poor rural smallholders in the north and the country as a whole can benefit from sensible economic policies that allow producers to receive prices that are closer to border-equivalent levels.

3. The impacts of pricing policies on land degradation, Malawi

This case study is based on Barbier (1998) and Barbier and Burgess (1992). Poor smallholders in Malawi often face important labour, land and cash constraints on their ability to invest in land improvements. During the 1970s and 1980s, major swings in relative producer prices in Malawi may have made it difficult for smallholders to plan and develop viable land management and cropping systems to counteract erosion. This may have affected the poorest smallholders especially, who rely on intercropping and relay cropping maize (*Zea mays*), groundnuts and pulses as a means to meeting nutritional needs, maintaining soil fertility and conserving soil. Some farmers may have abandoned these mixed cropping systems to plant as pure stands the more erosive crops, such as maize, cotton (*Gossypium* spp. and hybrids) and tobacco (*Nicotiana tabacum*), in response to higher relative prices for these crops. In addition, the uncertainty arising from the fluctuations in prices might have prevented poor smallholders from making land management and conservation investments to reduce erosion.

Until the early 1980s, prices for the three major food crops in Malawi, pulses, groundnuts and maize, did not increase substantially. Prices for pulses and groundnuts began increasing in the early 1980s, and were still rising rapidly at the end of that decade. Maize prices have been heavily controlled by government, and were not increased significantly until after the 1986/1987 season. Other key smallholder crops in Malawi are tobacco, cotton and cassava (*Manihot esculenta*). Again, the prices of the cash crops cotton and tobacco did not increase substantially until the early 1980s, with tobacco prices rising dramatically at the end of the decade. Cassava prices continued to remain low throughout the 1970s and 1980s.

These trends in individual crop prices can be aggregated to derive price trends for the 'less-erosive' as opposed to the 'erosive' crops. Determining which crops are 'less-erosive' is of course difficult. All annual crop cultivation will produce some soil erosion, runoff and fertility declines. However, some annual crops, e.g. pulses and groundnuts, offer better ground cover, soil fertility maintenance and soil structure cohesion than do others, e.g. maize, tobacco, cassava and cotton, thus reducing land degradation. Also, it is

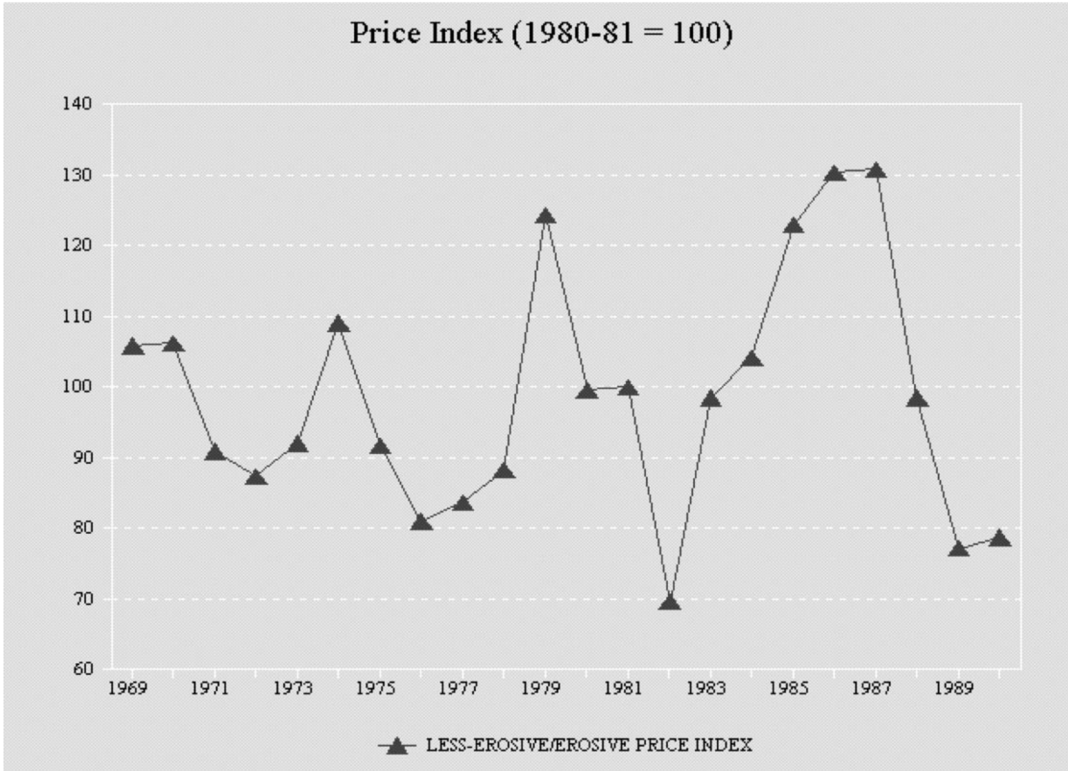

Fig. 1. Price ratio of less-erosive/erosive crops, Malawi.

not the crop per se which causes soil erosion but the method of cultivation and cropping pattern. In Malawi, smallholders often intercrop pulses and groundnuts, both with each other and with maize and/or cassava, thus reducing erosion of the entire cropping system. Thus, in the Malawi context, the major less-erosive crops are pulses and groundnuts, and the major erosive crops are maize, cassava, cotton and tobacco.

As indicated, with the exception of cassava, the prices of both less-erosive and erosive crops followed approximately the same price trends during the 1970s and 1980s. Consequently, as shown in Fig. 1, the ratio of less-erosive to erosive prices did not rise significantly over these two decades. However, Fig. 1 does indicate that this price index fluctuated considerably every few years, with the swings increasing dramatically during the 1980s.

The reason for this variability was the government's price fixing policy. Each year during these two decades, the Government of Malawi fixed the prices that it would pay for crops before the planting season. These prices were based on how much was bought and sold in markets, as well as whether there were sufficient aggregate supplies of food crops to meet domestic requirements or cash crops to meet export targets. This led to dramatic changes in the prices of individual crops from year to year, and as a result, farmers responded to changes in relative prices by frequently shifting their cropping patterns.

However, the long-term effects of such relative price fluctuations could be serious. In particular, smallholders intending to invest in new cropping patterns and systems may face substantial uncertainty and thus be less willing to undertake such investments. There are two implications for land management. First, farmers who are not incorporating less-erosive crops in their cropping systems may be less willing to do so since the price fluctuations indicate a high risk of investment from crop season to season and small long-term gains. Second, farmers who already incorporate less-erosive crops may have less incentive to invest in improvements to these mixed cropping systems, again because of the investment risks from seasonal fluctuations in relative prices and apparently insignificant long-term gains.

The extent to which smallholders in Malawi can anticipate or ‘predict’ the relative price of less-erosive to erosive crops is based on past price levels and trends. If farmers are to make significant land management investments in cropping patterns and systems, such as switching between erosive and less-erosive crops or substantially improving less-erosive cropping systems, then they need to anticipate future relative crop price trends. Unfortunately, a recent econometric analysis suggests that, throughout the 1970s and 1980s in Malawi, past relative prices of less-erosive to erosive crops were a poor indicator of future prices (Barbier, 1998). Since this implies that the relative price trend was highly unstable, then past prices during this period were not good guides to the future, and the uncertainty surrounding farmers’ investments was high.

Any significant impact of long-run price changes of less-erosive to erosive crops in Malawi should be reflected in changes in the returns associated with each type of crop. The relative returns in terms of gross margins per hectare of less-erosive to all erosive crops and of less-erosive to the high-value erosive crops (hybrid maize, cotton and tobacco) are displayed in Fig. 2. The relative gross margins of less-erosive crops clearly fluctuated over the 1980s, peaking in the mid-1980s and falling sharply towards the end of the decade. The fluctuation was mainly due to rapid changes in the returns of groundnuts relative to maize, which in turn were influenced by policy reversals on the relative pricing of these two crops during

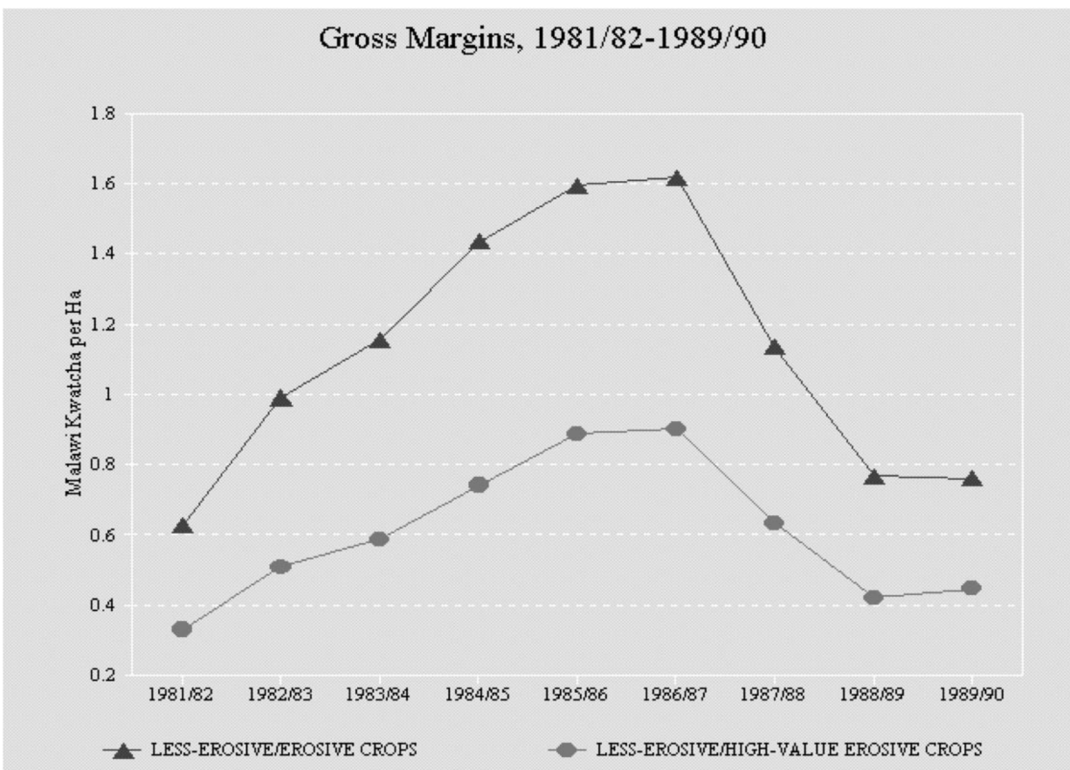

Fig. 2. Gross margins of less-erosive/erosive crops, Malawi.

the 1980s. However, even when the relative returns to groundnuts were high, the gross margins of all less-erosive crops in aggregate remained below that of high-value erosive crops. This is indicated in Fig. 2, which shows that the ratio of the gross margins of less-erosive crops with respect to high-value erosive crops never exceeded one throughout the 1980s. Over this period, farmers who monocropped the latter crops therefore had little incentive to change to an intercropped system that incorporates less-erosive crops.

To summarize, this case study of Malawi illustrates how fluctuations in relative crop prices and returns induced by agricultural pricing policy can exert a significant impact on the incentives for smallholders to invest in improved cropping systems and land management by increasing the degree of price risk. The dynamics of price risk may produce the following effects.

Given the very small margins for risk among most smallholders and the widespread prevalence of household food insecurity, the uncertainty arising from fluctuating prices and returns is not conducive to improving farming systems, incorporating new crops or investing in substantial improvements in existing cropping patterns, cultivation practices and conservation efforts. Throughout the 1980s, the relative poor returns of the less-erosive crops (groundnuts and pulses) to the high-value erosive crops (hybrid maize, cotton and tobacco) may have further restricted the income of those poorer households who continued to rely on intercropped systems, with consequences for both their food security and land management. Farmers who monocropped the high-value erosive crops had little incentives to incorporate less-erosive crops in their farming systems. Finally, the asymmetrical impacts of pricing for most households, i.e. that food-deficit households are likely to feel the impact of higher food prices as consumers rather than respond as producers to increase production, may have reinforced both the disincentive effect of price fluctuations on investment in improved farming systems and land management, as well as the income constraints faced by poorer households.

Further detailed analysis of these effects is required both in Malawi and in other African countries to improve our understanding of how relative price changes influence smallholder soil conservation and land management investment decisions.

4. An analysis of resource entitlement loss, northern Nigeria

This case study is based on Barbier and Thompson (1998). See also Barbier et al. (1993). Many irrigation development projects in semiarid parts of Africa end up displacing poor farmers and pastoralists from their traditional sources of water and land, thus forcing them to move to more fragile environments prone to land and resource degradation. Often this environmental entitlement loss occurs needlessly, because planners of irrigation projects fail to consider the potential impacts of upstream water diversion on downstream users of water and land. The following case study from northern Nigeria illustrates this prevalent problem.

In Northeast Nigeria, an extensive floodplain has been created where the Hadejia and Jama'are Rivers converge to form the Komadugu Yobe River which drains into Lake Chad. Although referred to as wetlands, much of the Hadejia–Jama'are floodplain is dry for some or all of the year. Nevertheless, the floodplain provides essential income and nutrition benefits in the form of agriculture, grazing resources, non-timber forest products, fuelwood and fishing for local populations. The wetlands also serve wider regional economic purposes, such as providing dry season grazing for seminomadic pastoralists, agricultural surpluses for Kano and Borno states, groundwater recharge of the Chad formation aquifer and 'insurance' resources in times of drought. In addition, the wetlands are a unique migratory habitat for many wildfowl and wader species from the Northern Hemisphere, and contain a number of forestry reserves.

However, in recent decades the Hadejia–Jama'are floodplain has come under increasing pressure from drought and upstream water developments. The maximum extent of flooding has declined from between 250 000 and 300 000 ha in 1960s and 1970s to around 70 000 and 100 000 ha more recently. Drought is a persistent, stochastic environmental problem facing all sub-Saharan arid and semiarid zones, and the main cause of unexpected reductions in flooding in drought years. The main long-term threat to the floodplain is water diversion through large-scale water projects on the Hadejia and Jama'are Rivers. Upstream developments are affecting incoming water, either through dams altering the timing and size of flood flows or through diverting surface or groundwater for irrigation. These developments have been taking place without consideration of their impacts on the Hadejia–Jama'are floodplain or any subsequent loss of economic benefits that are currently provided by use of the floodplain.

The largest upstream irrigation scheme at present is the Kano River Irrigation Project (KRIP). Water supplies for the project are provided by Tiga Dam, the biggest dam in the basin, which was completed in 1974. Water is also released from this dam to supply Kano City. The second major irrigation scheme within the river basin, the Hadejia Valley Project (HVP), is under construction. The HVP will be supplied by Challawa Gorge Dam on the Challawa River, upstream of Kano, which was finished in 1992. Challawa Gorge may also provide water for Kano City water supply. A number of small dams and associated irrigation schemes have also been constructed or are planned for minor tributaries of the Hadejia River. In comparison, the Jama'are River is relatively uncontrolled with only one small dam across one of its tributaries. However, plans for a major dam on the Jama'are at Kafin Zaki have been in existence for many years, which would provide water for an irrigated area totalling 84 000 ha. Work on Kafin Zaki Dam has been started and then stopped a number of times, most recently in 1994, and its future at present is unclear.

A combined economic and hydrological analysis was recently conducted to simulate the impacts of these upstream projects on the flood extent that determines the downstream floodplain area (Barbier and Thompson, 1998). The economic gains of the upstream water projects were then compared to the resulting economic losses to downstream agricultural, fuelwood and fishing benefits.

Table 2 indicates the scenarios that comprise the simulation. Since Scenarios 1 and 1a reflect the conditions without any of the large-scale water resource schemes in place within the river basin they are employed as baseline conditions against which Scenarios 2–6 are compared. Scenario 2 investigates the impacts of extending the KRIP-I to its planned full extent of 22 000 ha without any downstream releases. In contrast, Scenario 3 simulates the impacts of limiting irrigation on this project to the existing 14 000 ha to allow a regulated flood from Tiga Dam in August to sustain inundation within the downstream Hadejia–Jama'are floodplain. Challawa Gorge is added in Scenario

Table 2
Scenario for upstream projects in the Hadejia–Jama'are River Basin, northern Nigeria (from Barbier and Thompson, 1998)

Scenario (time period)	Dams	Regulated releases (10^6 m^3)	Irrigation schemes[a]
1 (1974–1985)	Tiga	Naturalized Wudil flow (1974–1985)	No KRIP-I
1a (1974–1990)	Tiga	Naturalized Wudil flow (1974–1990)	No KRIP-I
2 (1964–1985)	Tiga	None	KRIP-I at 27 000 ha
3 (1964–1985)	Tiga	400 in August for sustaining floodplain	KRIP-I at 14 000 ha
4 (1964–1985)	Tiga	None	KRIP-I at 27 000 ha
	Challawa Gorge	348 per year for HVP	
	Small dams on Hadejia tributaries		
5 (1964–1985)	Tiga	None	KRIP-I at 27 000 ha
	Challawa Gorge	348 per year for HVP	
	Small dams on Hadejia tributaries		
	Kafin Zaki	None	84 000 ha
	HVP	None	12 500 ha
6 (1964–1985)	Tiga	350 in August	KRIP-I at 14 000 ha
	Challawa Gorge	248 per year and 100 in July	
	Small dams on Hadejia tributaries		
	Kafin Zaki	100 per month in October–March and 550 in August	None
	HVP	Barrage open in August	8000 ha

[a] KRIP-I: Kano River Irrigation Project Phase I; HVP: Hadejia Valley Project.

Table 3
Impact of scenarios on mean peak flood extent and gains in total irrigated area

	Scenario 1	Scenario 1a	Irrigated area (km^2)
Scenario 2	−150.62	−211.20	270
Scenario 3	−95.25	−55.83	140
Scenario 4	−265.02	−325.60	270
Scenario 5	−870.49	−931.07	1235
Scenario 6	−574.67	−635.25	220

4 and the simulated operating regime involves the year-round release of water for the downstream HVP, but not for sustaining the Hadejia–Jama'are floodplain. Scenario 5 simulates the full development of the four water resource schemes without any releases for the downstream floodplain. In direct comparison, Scenario 6 shows full upstream development, but less upstream irrigation occurs in order to allow regulated water releases from the dams to sustain inundation of the downstream floodplain.

In Table 3, the impacts of Scenarios 2–6 upon peak flood extent downstream are evaluated as the difference between maximum inundation predicted under each of these scenarios and the peak flood extents of the two baseline scenarios. The gains in upstream-irrigated area are also indicated for each scenario in Table 3. The estimated floodplain losses are indicated in Table 4 for each scenario compared to the baseline Scenarios 1 and 1a. Given the high productivity of the floodplain, the losses in economic benefits due to changes in flood extent for all scenarios are large, ranging from US$ 2.6–4.2 million to US$ 23.4–24.0 million. As expected, there is a direct trade-off between increasing irrigation upstream and impacts on the wetlands downstream. Scenario 3, which yields the lowest upstream irrigation gains, also has the least impact in terms of floodplain losses, whereas Scenario 5 has both the highest irrigation gains and floodplain losses. The results confirm that in all the scenarios simulated, the additional value of production from large-scale irrigation schemes does not replace the lost production attributed to the wetlands downstream. Gains in irrigation values account for at most around 17% of the losses in floodplain benefits.

This combined hydrological–economic analysis would suggest that no new upstream developments should take place in addition to Tiga Dam. Moreover, a comparison of Scenario 3 to Scenario 2 in the analysis shows that it is economically worthwhile to reduce floodplain losses through releasing a substantial volume of water during the wet season, even though this would not allow Tiga Dam to supply the originally planned 27 000 ha on KRIP-I.

Although Scenario 3 is the preferred scenario, it is clearly unrealistic. As indicated above, Challawa Gorge was completed in 1992, and in recent years several small dams have been built on the Hadejia's tributaries while others are planned. Thus, Scenario 4 most closely represents the current situation, and Scenario 5 is on the way to being implemented, although when the construction of Kafin Zaki Dam might occur is presently uncertain. As indicated in Table 4, full implementation of all the upstream dams and large-scale

Table 4
Impact of scenarios in terms of losses in floodplain benefits versus gains in irrigated production, net present value (US$ 1989/1990 prices)

	Irrigation value, I[a]	Scenario 1			Scenario 1a		
		Floodplain loss, F[b]	Net loss, $F-I$	I as % of F	Floodplain loss, F[b]	Net loss, $F-I$	I as % of F
Scenario 2	682983	−4045024	−3362041	16.88	−5671973	−4988990	12.04
Scenario 3	354139	−2558051	−2203912	13.84	−4184999	−3830860	8.46
Scenario 4	682963	−7117291	−6434328	9.60	−8744240	−8061277	7.81
Scenario 5	3124015	−23377302	−20253287	13.36	−24004251	−20880236	13.01
Scenario 6	556505	−15432952	−14876447	3.61	−17059901	−16503396	3.26

[a] Based on the mean of the net present values per hectare production benefits for the Kano River Irrigation Project Phase I (see Barbier and Thompson, 1998), and applied to the gains in total irrigation area shown in Table 3.

[b] Based on the mean of the net present values of total benefits for the Hadejia–Jama'are floodplain (see Barbier and Thompson, 1998) averaged over the actual peak flood extent for the wetlands of 112 817 ha in 1989/1990 and applied to the differences in mean peak flood extent shown in Table 3.

irrigation schemes would produce the greatest overall net losses, around US$ 20.2–20.9 million.

These results suggest that the expansion of the existing irrigation schemes within the river basin is effectively ‘uneconomic’. The construction of Kafin Zaki Dam and extensive large-scale formal irrigation schemes within the Jama’are Valley do not represent the most appropriate developments for this part of the basin. If Kafin Zaki Dam were to be constructed and formal irrigation within the basin limited to its current extent, the introduction of a regulated flooding regime (Scenario 6) would reduce the scale of this negative balance substantially, to around US$ 15.4–16.5 million. The overall combined value of production from irrigation and the floodplain would however still fall well below the levels experienced if the additional upstream schemes were not constructed.

Such a regulated flooding regime could also produce additional economic benefits that are not captured in the hydrological–economic analysis. Greater certainty over the timing and magnitude of the floods may enable farmers to adjust to the resulting reduction in the risks normally associated with floodplain farming. Enhanced dry season flows provided by the releases from Challawa Gorge and Kafin Zaki dams in Scenario 6 would also benefit farmers along the Hadejia and Jama’are Rivers while the floodplain’s fisheries may also experience beneficial impacts from the greater extent of inundation remaining throughout the dry season. The introduction of a regulated flooding regime for the existing schemes within the basin may be the only realistic hope of minimizing floodplain losses. Proposed large-scale schemes, such as Kafin Zaki, should ideally be avoided if further floodplain losses are to be prevented. If this is not possible, the designs for water resource schemes should enable the release of regulated floods in order to, at least partly, mitigate the loss of floodplain benefits which would inevitably result.

Currently, as a result of such economic and hydrological analyses of the downstream impacts of upstream water developments in the Hadejia–Jama’are floodplain, both the States in northern Nigeria and the Federal Government have become interested in developing regulated flooding regimes for the upstream dams, and have been reconsidering the construction of Kafin Zaki Dam.

5. Economy-wide policies and land conversion, western Ghana

The following study is based on López (1997), and it is also summarized in Munasinghe and Cruz (1995). The following case study illustrates the potential linkage between economy-wide structural reforms and land management decisions of poor farmers. This issue is particularly important in Africa, given that since the mid-1980s many African countries have introduced such reforms as part of major economic structural adjustment programs. However, to date there has been very little analysis of the impacts of economy-wide reforms in African countries on the land use decisions of poor rural households. The exception is a recent study by López (1997), which analyses the impact of trade liberalization on land conversion in western Ghana.

Since 1983, Ghana has introduced major structural reforms to its economy, including liberalizing its exchange rate, reducing public sector spending, decreasing industrial protectionism and removing distortions in the prices of agricultural commodities, especially export crops such as cocoa. Despite these reforms, further trade liberalization measures could still be implemented in Ghana, including further decreases in protection to the import substitution sector, particularly cereals, and additional reductions on the implicit export tax to agricultural commodities.

These trade liberalization reforms would have an important impact not only on the whole economy but also on the traditional agricultural sectors of Ghana. One such sector is the predominantly shifting cultivation agricultural systems of western Ghana. In such systems, land is cultivated for 1 or 2 years and then left idle for 4–10 years to restore its productive capacity. In the traditional bush-fallow rotation, the biomass that is regenerated through fallowing the land serves as natural fertilizer when it is burned and reabsorbed in the topsoil when the land is next prepared for cultivation. Biomass is therefore an important input in long-term agricultural production, and depletion of biomass through either shortening of fallow periods or more extensive land cultivation is likely to cause land degradation and loss of productivity. As naturally forested land is not individually owned, too much conversion of this land can occur if there are insufficient communal controls on overexploitation. However, if

Table 5
The demand for land by shifting cultivators, western Ghana (from López, 1997)

Explanatory variable	Short-run elasticity (*t*-statistic)	Long-run elasticity (*t*-statistic)
Dependent variable: area cultivated by each household, 1988–1989 (double-log specification)		
Constant	7.10 (2.66)	8.85 (4.0)
Family members	0.37 (2.33)	–
Wage/agricultural output price	−1.01 (−2.19)	−1.26 (−3.13)
Tools	0.27 (1.94)	0.42 (3.32)
% of fallow land to total land	−0.19 (−0.91)	–
Dummy for cocoa producer[a]	0.89 (4.37)	0.86 (4.34)
Dummy for Ashanti–Bron ethnic group[b]	−0.57 (−2.44)	−0.69 (−2.97)
Dummy 89	1.49 (5.77)	1.44 (6.57)
Number of observations	139	139
R^2	0.54	0.51
Adjusted R^2	0.51	0.49
F-test	21.67	27.94

[a] Takes value 1 if the household grows cocoa and 0 otherwise.
[b] Takes value 1 if the household belongs to the Ashanti–Bron ethnic group and 0 otherwise.

communal controls are adequate, then the community can gain through avoiding the costs to all farmers of excessive loss of biomass, erosion and flooding in the communal area.

By modelling the agricultural production decisions of shifting cultivators in western Ghana, López (1997) has been able to estimate the key determinants of both agricultural output and the demand for cultivated land by individual farming households. First, it was estimated that biomass, measured in terms of the proportion of land under forest cover, contributes 15–20% of the value of agricultural output in the bush-fallow systems. Second, several factors appear to influence the total land area cultivated by farmers. The results of this latter analysis are indicated in Table 5.

The key variable is the effect of the wage–price ratio on the demand for land. As Table 5 indicates, a decrease in the wage rate or an increase in agricultural prices faced by farmers in western Ghana will lead to an increase in the area of land that they will cultivate. In other words, if trade liberalization leads to rising agricultural prices for farmers in the region, they are likely to respond by increasing their cultivated area. Farmers will do this either by shortening their fallow rotations, or equivalently, by finding new forested land to convert. In both cases, there is an overexploitation of biomass and loss of long-term productivity, since the proportion of fallow to cultivated land will fall in the bush-fallow system.

Through a general equilibrium model, López (1997) estimates that the overall impacts of trade liberalization will on an average cause a 2.5–4.4% decline in biomass in western Ghana as a result of farmers increasing cultivated area. Thus, although the result of reducing trade distortions is to increase income in the national economy, these income gains may be more than offset by the loss in long-term income from less sustainable and productive agricultural systems in western Ghana. The overall economy may gain, but poor smallholders dependent on bush-fallow cropping systems could lose through greater land conversion and degradation.

However, there are of course one or two caveats to this analysis. First, as we saw in the previous case study for Malawi, land use decisions by poor smallholders may be influenced not just by aggregate levels of prices, but also by short-term fluctuations in relative prices of and returns to different crops, in particular less-erosive versus erosive crops. Thus, economy-wide reforms such as trade liberalization may affect the prices of various food and cash crops differently, which in turn will affect both the choice of alternative crops and farming systems adopted by smallholders, including shifting cultivators in western Ghana.

In addition, a recent study in Ghana of the effects of economy-wide reforms on the price-adjustment process in local markets suggests that price responsiveness and volatility in outlying markets will depend on their degree of interdependence with the main central markets in which the price reforms are initiated (Badiane and Shively, 1998). That is, the extent to which central and outlying markets are integrated has important implications for long-run changes in transport costs and the evolution of prices in local markets. If market integration is weak, price responses in remote outlying markets may be more volatile and difficult to predict, and may even differ significantly from the impacts of pricing reforms on central markets. Consequently, the price transmission process from central to outlying markets that occurs after, i.e. trade liberalization may not lead to the anticipated changes in local prices, thus making it difficult to predict the impacts of an economy-wide reform on the land management decisions of poor smallholders in remote and marginal farming areas.

6. Improved land resource management, Machakos District, Kenya

The final case study looks at a well-known 'success story' of improved long-term land resource management, the Machakos District of east-central Kenya. It is based on English et al. (1994). See also Tiffen et al. (1994) and Pagiola (1994).

In the 1930s, the semiarid Machakos District, inhabited by the Akamba tribe, was considered to be suffering from acute land degradation, to the extent that the region's ability to support both its human and livestock population was in doubt. This situation continued unabated through the 1970s, when projections for the region of a 'Malthusian-type' poverty trap, land abandonment and large out-migrations, widespread deforestation and chronic fuelwood shortages were the norm.

However, after nearly 30 years, none of these environmentally and economically catastrophic events have yet to occur in Machakos District. In fact, recent studies that have compared agricultural development and land management in the region over the past 50 years or so have concluded that, although the population in Machakos is now five times as large, the value of agricultural output per head in real terms is three times greater than in the 1930s (English et al., 1994; Tiffen et al., 1994). As shown in Table 6, even compared to the late 1970s, the main indicators of land resource management and economic development have shown a substantial improvement.

The source of this success in Machakos District appears to be innovation, particularly in terms of farming systems, choice of crops and the adoption of improved land management techniques. Consequently, rapid population growth and major social and economic change have not resulted in an environmental and economic disaster for the region; to the contrary, more effective land management, improved agricultural productivity and higher per capita incomes have occurred.

Although substantial land use change has taken place in Machakos, it has not led to the type of long-term 'cumulative causation' between land conversion and degradation described in the first lecture. The area under cultivation has expanded by four or five times its 1930s level, but this is partly because at least one-third of the District's population is now settled in an area previously infested with tsetse fly. Although the traditional bush-fallow rotation and livestock herding systems are no longer viable due to the reduction in bush, scrub and general grazing areas, they have been replaced by improved farming systems oriented toward marketed rather than subsistence output. For example, staple food production appears to have stabilized at about the level required for basic subsistence, about 200 kg of maize equivalent per head per year. Instead, the increased per capita value in agricultural production has come almost entirely in the form of cash crops, initially coffee and cotton and more recently fruit and horticultural crops.

Moreover, agricultural innovation has gone hand-in-hand with investments in improved land management practices. Besides, the adoption of a wider selection of crops, numerous new technologies and changes in agricultural practices have been recorded, including the adoption of ox-drawn ploughs, short duration maize varieties, stall feeding and fodder crops for intensive livestock rearing, and monocropping the main annual crops in rows to facilitate both planting, weeding and harvesting. Important innovations in land management have also occurred, such as extensive terracing, contour cultivation with oxen, land preparation before the rains, and the use of animal manure for fertilizer. The most striking land improvement investment has been terracing. More than 200 000 ha of land have been terraced, which is estimated to have cost over $50 million in 1990 prices (English et al., 1994).

Table 6
Indicators of land resource management, Machakos District, Kenya (from English et al. (1994))

Indicators	Conditions as seen by	
	Bernard (1978)	English et al. (1994)
Soil depletion and erosion	Soil depletion and erosion are still major problems	No evidence that soil fertility is declining, and while some erosion is occurring, this appears to be under control and not causing any significant loss of productive capacity
Declining crop yields	Lack of data	No evidence
Use of 'marginal' lands	Pressure exerted on marginal lands can further promote deteriorating conditions	No evidence that farming systems in these areas are leading to long-term degradation
Changing crop emphases	Switching to crops tolerant of poor soils	Not borne out, e.g. continued preference for maize rather than sorghum, and shift to horticultural crops
Reduction of fallow	As the cycle of cultivation and fallow is reduced under increasing pressure, soils experience nutrient impoverishment	Reduction has occurred, but has been replaced by new, more productive indigenous systems
Food shortages and malnutrition	Movement of people into marginal lands has adversely affected diets	Occur in exceptional years, but malnutrition not severe except in socially deprived families, even in the dry 1970s
Landlessness, land disputes, etc.	Not sufficiently examined	No evidence one way or the other
Rural indebtedness	Not sufficiently examined	No evidence one way or the other
Underemployment and unemployment	Lack of 'jobs', but labour still a significant constraint for agriculture	Becoming a felt problem in some areas
Out-migration	Continues at a substantial rate: in the hill country half the young men are off to Nairobi and Mombassa	Appears to have declined as the sex ratio has moved closer to unity and there is no evidence of significant movement out of the district by both sexes

Yet, without such substantial investments in long-term productivity, the complementary and widespread changes in farming systems to commercial cropping could not have taken place. Currently in Machakos, 100% of the area cultivated is terraced, which in turn allows this land to be cultivated continuously.

A recent study of land resource management in Machakos has suggested that several lessons can be learned from this success story (English et al., 1994). These 'lessons learned' echo many of the key conclusions that we have explored throughout these three lectures.

First, from the farmers' perspective, the adoption of both improved land management and agricultural innovations have had to be compatible with the existing farming systems. Smallholders did not adopt recommended conservation measures and agricultural technologies uniformly, but had to experiment, adapt and improve them within their own farming systems. This degree of flexibility and adaptability in terms of techniques and improvements in turn increased rather than reduced the number of viable and profitable land use options available to smallholders; there was no dependence on a 'set' conservation technology or farming system 'package' for all farmers in the region.

In addition, the adopted improvements in land management and conservation not only needed to be compatible with existing farming practices and systems but also had to be affordable. For example, the considerable investments in the region in bench terracing, trees, woodlots, dams and other infrastructure were made without any subsidies or credit targeted specifically for conservation investments. Instead, cash earned from off-farm work and from the sale of commercial crops were used to fund the necessary purchased inputs that were required, along with on-farm family and communal labour, for soil conservation and land improvements. For most farmers, the long-term gains in terms of improved productivity and income appear to have justified the upfront investments of labour and cash required for better land management.

One recent analysis of the returns to Machakos farmers suggests that these upfront costs of bench terracing are considerable, amounting initially to Kenya Shillings (KSh) 3420 per ha (US$ 57 per ha). In addition, the annual costs of maintaining terraces is KSh 470 (US$ 7.83), and the reduction in cropping area leads to a permanent loss in annual income of KSh 350 (US$ 5.83) (Pagiola, 1994). As a consequence, the internal rate of return to terracing is just over 10% for crop cultivation on a 15% slope, and the investment in terracing would only be repaid after 48 years. On steeper slopes, the investment appears more worthwhile, i.e. on a 20% slope the payback period is reduced to 13 years. Nevertheless, the analysis suggests that farmers are unlikely to undertake terracing unless their tenure to the land is sufficient to cover these long repayment periods and such conservation investments are also co-ordinated with other improvements to their cropping systems that yield long-term gains.

The fact that so many farmers in Machakos did undertake terracing on their own initiative would suggest that these conditions were largely met. In particular, investments in controlling land degradation became economically profitable to the Machakos farmers because these efforts were accompanied by the eventual shift to more intensive farming systems producing higher-valued commercial crops. Increased market-orientation of agriculture in the region and higher farming incomes raised the returns and value to the land, which in turn facilitated the adoption of new agricultural and land management practices that encouraged more intensive and sustainable land uses. Thus better land resource management, improvements in farming systems, higher returns to the land, and ultimately, agricultural development were not pursued separately but were necessary complements in the overall rural development of Machakos.

From a policy perspective, several lessons can be learned from the Machakos experience. First, the conventional land management approach, which is to prescribe one or two uniform soil conservation technologies or a limited and fixed range of land use and farming systems, was also tried in Machakos over the years and failed. Instead, the approaches that appear to have had more of a positive influence in fostering effective and improved land resource management by farmers were those public policies and investments which also promoted agricultural innovation and improvements generally. These included: (1) Policies that assisted the market-orientation of farm production and access to market outlets for products. (2) Policies that influenced farmers' access to agricultural information on the availability of a wide range of new crops and technically viable land use options, either directly through research and extension efforts or indirectly through improving the level of literacy and education of farmers. (3) Policies that allowed some devolution to the local level of decisions concerning the allocation of resources and planning agricultural development.

Perhaps the most striking aspect of the above public policies and investments is that they are fairly straightforward. There does not appear to have been any special or unique approach developed for Machakos. Consequently, there is no reason why similar policies cannot be adopted and implemented across many other regions of Africa where poor rural smallholders are struggling with the dual problem of chronic land degradation and agricultural underdevelopment. Moreover, as emphasized, such policy approaches that promote improvements in the general economic and market conditions faced by poor farmers on existing agricultural land could be much more cost-effective and have wider impacts than more conventional land management programmes that focus on encouraging farmers to adopt a limited set of prescribed crops, farming systems and soil conservation measures.

However, there are a number of special features unique to the Machakos case which may limit the replicability of its long-term 'success' elsewhere in Africa. First, as pointed out by others, there have been some important institutional dynamics that underlie the successful implementation of long-term agricultural development and land management efforts in Machakos (English et al., 1994; López, 1998). Communities in the region do not appear to have a rigid social structure which inhibits individuals, or subgroups, from collaborating, as there are no rigid barriers based on factors such as tribal or clan loyalties, religion, ethnic background or political group, sex, class and caste. Prevailing institutional conditions in Machakos not only were able to cope with rapid social and economic change but also clearly diffused any internal conflicts over land and resource use, as well as prevented potential problems of resource displacement or entitlement loss through the actions of outsiders. These institutional dynamics have also been important to maintaining and supporting the unique system of customary land rights that in practice operate as de facto private ownership.

Second, the rapid integration of the local economy of Machakos within the larger market economy of Kenya has been greatly assisted by its geographical location. The district headquarters is only 60 km from Nairobi, Kenya's capital as well as its largest city and market. Not only has this facilitated the market-orientation of agriculture in Machakos, but it has also meant that government investments in improved roads and market access, provision of extension and other public services and co-ordination with local officials have been both less costly and more easily implemented.

Finally, Machakos District has been the target of a long tradition of official community development support, going back to the 1950s. The special attention afforded this particular region of Kenya is why its long-term land resource and agricultural development efforts have been so well documented and studied. This long-term focus on Machakos must have generated some important 'spillover' benefits for local farmers, even if many specific government programmes for the district were not directly successful. For example, it has been noted that early rural development and soil conservation programmes, including the compulsory bench terracing efforts, at least allowed local farmers to become familiar with a variety of soil conservation technologies, as well as introduced them to a range of agricultural innovations and potential cash crops.

These unique features underlying long-term agricultural and land management developments in the Machakos District must not be forgotten when considering the possible replicability of this success story in other parts of Africa. As noted in Section 1, many impoverished rural households find themselves in remote marginal areas, where access to central markets and government services is poor, where existing institutional dynamics are too weak either to prevent resource conflicts and environmental entitlement loss or to ensure long-term and secure property rights, and where local farming communities have been largely neglected by government development efforts that have instead concentrated on farmers in more favourable and central agricultural areas.

7. Conclusion

This paper has examined a number of case studies across Africa that have focussed on the role of policy in poverty–land degradation linkages. These studies not only demonstrate how policies may influence the economic incentives of poor smallholders to manage their land but also indicate that a critical concern of policy analysis must be to understand the incentives that determine poor farmers' response to land degradation. To design better policies to tackle both rural poverty and land degradation, we must begin with a better understanding of how existing policies and public investments affect the land management and agricultural decisions of rural smallholders.

Although poverty–environment linkages may be pervasive throughout rural Africa, and pose daunting and formidable challenges to policy makers, such problems are not insurmountable. As emphasized in this final lecture, we can find ways to overcome rural poverty and land degradation linkages in Africa, provided that we analyse carefully the market, institutional and policy failures that exacerbate such problems and improve our understanding of why certain policies and investments have succeeded, while others have not. Improved land management, poverty reduction and agricultural development are critically related goals for rural Africa, and must be treated as such in the design of better policies for economic development and poverty alleviation.

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