Chapter 5
The impacts of irrigated agriculture

In addition to altering the level and composition of factors of production and raising or lowering unit production costs, the introduction of irrigation has an impact on the level, stability, composition and seasonality of agricultural output and on the physical characteristics of the commodity harvested. Using sub-Saharan Africa examples, this chapter analyses these impacts and how they in turn affect the structure and efficiency of product processing and marketing systems, the level of market prices, and the ability of producers to exploit market opportunities.

Before relating this to the specifics of sub-Saharan Africa irrigation opportunities, the chapter closes with a similar consideration of the likely social and environmental impacts of introducing irrigation.

VALUE CHAINS AND THE INFLUENCE OF IRRIGATION ON MARKETING AND PROCESSING

Most sub-Saharan Africa agricultural production is marketed and physically transformed prior to final consumption or industrial use. This includes a significant proportion of the foodstuffs produced on small-scale subsistence farms. Such farms frequently sell much of their output to meet urgent cash needs and then seek to buy staple foodstuffs later in the crop year. Given that a large proportion of total sub-Saharan Africa agricultural output is marketed, the efficiency of markets is vital both for the livelihoods of farm households and for other rural households that rely on the agriculture sector for employment.

Until the recent period of structural adjustment, grains, tropical beverages and most industrial crops grown in sub-Saharan Africa were processed and marketed either under systems operated by state-owned enterprises or under systems that involved some form of state price control. These have now largely been replaced by systems in which individuals, private firms and cooperatives undertake the processing and marketing. These systems rely on competitive forces to determine prices. The prices offered to producers of agricultural commodities depend on the costs incurred at each stage of the system and on the extent of competition at each point at which the commodity is traded.

The former state-run systems were designed to be compatible with the production and market characteristics of the commodity in question. Under a free market, the structure of marketing systems evolves over time to suit the characteristics of the commodity, often through a painful process that involves the collapse of unsuitable systems and the failure of enterprises involved in them.

As irrigation affects the production and market characteristics of agricultural commodities, it influences the evolution of marketing systems, their structure, and the efficiency at which they operate.

SPATIAL AND TEMPORAL IMPACTS

Spatial impacts

Irrigation affects the spatial distribution of agricultural production by allowing: (i) the growing of crops on land that was unable to sustain agriculture under rainfed conditions; (ii) the more intensive growing of existing crops; and (iii) the growing of alternative crops. For example, irrigation has allowed desert, semi-desert and low-productivity rangeland in Namibia, Kenya and Sudan to be converted to the production of fruits and cotton. In South Africa and other sub-Saharan Africa countries, irrigation has been utilized to raise the productivity of existing crop production, most notably the production of maize and vegetables. In central Kenya, irrigation has allowed some 5 000 ha that had been devoted to grazing and the growing of maize and other rainfed crops to be converted to rice production. In Swaziland, former low-veldt rangeland has been irrigated and utilized for the production of sugar cane.

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As irrigation normally leads to substantially higher yields, it has the effect of concentrating production spatially. This tendency is reinforced by engineering considerations relating to the supply of water, which frequently requires that irrigated land comprises a single contiguous area. The tendency for irrigation to lead to concentrated production applies to all irrigation regardless of the prior use of the land.

The concentration of production raises the efficiency of marketing by allowing the exploitation of economies of scale, especially in transport. This applies both to road construction and maintenance and to vehicle use. Concentrated production also allows larger and more efficient processing units and reduces the distances over which the raw commodity is transported to a processing unit. The benefits that stem from this differ between commodities depending on the value-to-weight ratio of the raw commodity, its perishability, the extent to which it is damaged during transport, and weight loss during processing. Of the main commodities grown under irrigation in sub-Saharan Africa, seed cotton is exceptionally bulky and sugar cane is both bulky and perishable. For both these commodities, but especially for sugar cane, the majority of the weight of the harvested commodity comprises low-value by-products that are removed during primary processing. For such commodities, the relative processing and marketing advantages afforded by irrigation are greater than for crops that are storable, are not easily damaged during transportation, are not exceptionally bulky, and which lose little weight during processing. The main sub-Saharan Africa crops that fall into this category are the staple grains, of which maize is the most important for food security. However, as yet, maize is largely insignificant as an irrigated crop, as shown in Table 15.

On balance, the concentration of production afforded by irrigation probably gives fruits and vegetables less of a marketing and processing edge than it does for bulky crops such as cotton and sugar.

Vegetables and fruits vary significantly in terms of all the important variables that relate the spatial production characteristics of irrigation to processing and marketing efficiency. However, the generally labour-intensive nature of post-harvest activities for fruits and vegetables means that economies of scale in these activities are generally low. Most fruits and vegetables also lose little weight during “processing”, which typically comprises only cleaning, grading and packing (fruits that are dried being the exception). Against this, most fruits and vegetables are highly perishable and easily damaged during handling and transport. On balance, the concentration of production afforded by irrigation probably gives fruits and vegetables less of a marketing and processing edge than it does for bulky crops such as cotton and sugar.

The concentrated production afforded by irrigation tends to lead to more-competitive assembly markets as it increases the number of traders able to operate viably in a particular area. It also reduces the cost of tracing the origin of products and thereby increases the potential for small-scale farmers to sell to supermarkets and to other buying enterprises that seek to trace products to their source. Concentrated production also increases the feasibility of marketing by a single agency by reducing the costs of dealing with a set of small-scale farmers. The marketing agency could be either a farmers cooperative or association or an enterprise such as a ginnery company. Contract farming organized by ginnery companies and other processors has been particularly successful in sub-Saharan Africa as a replacement for former state-run single-channel marketing systems (FAO, 2001). The concentration afforded by irrigation helps increase the feasibility of contract farming by making it more difficult for farmers to engage in undetected side-selling.

TABLE 15
Irrigated maize in sub-Saharan Africa for the baseline year

Region	Irrigated maize area as % of total maize area	Irrigated maize production as % of total maize production
Central	0.00	0.00
Eastern	1.45	2.09
Gulf of Guinea	0.29	0.70
Indian Ocean Islands	0.00	0.00
Republic of South Africa	3.47	8.99
Southern	0.29	0.61
Sudano-Sahelian	9.11	8.86
Sub-Saharan Africa	1.36	3.40

Against the generally positive impacts that spatially concentrated irrigated production has on marketing is the fact that the areas that can be irrigated most effectively may be distant from markets. For example, in Namibia, the only significant permanent rivers are in the extreme north and south of the country. Population density is low in the north and exceptionally low in the south. In the case of irrigation from the Orange River in the south, produce has to travel long distances to markets. Such new irrigation may only be commercially viable if new transport links are constructed, which may make the full investment package unattractive in terms of net benefits. While this can be a major problem that inhibits the development of irrigation, integrated irrigation development may have the desirable long-term side-effect of opening up new areas of the country to more widespread economic development. Indeed, governments may construct irrigation schemes in remote areas as part of a national strategy to decentralize development or stablilize rural communities. However, the general experience with the development of small-scale irrigation schemes in areas not effectively linked to markets has been disappointing.

Temporal impacts

Irrigation has the major advantage that it reduces dependence on seasonal weather patterns. This, coupled with control of the input of water, allows growing cycles to be reduced in length and crops to be established and raised during seasons with little rainfall. The impact of this on output depends principally on whether the crop is a perennial or an annual. In the former case, irrigation may allow harvesting throughout most or all of the year, as is typically the case for sugar cane, or there may still be distinct seasons, as is usually the case for tree or vine-grown fruits. For annual crops, control of the timing of irrigation may allow some variation in the timing of the harvest, permitting intra-annual market-price patterns to be exploited. For example, irrigation coupled with the application of chemical ripeners allows grapes to be harvested in central and southern Namibia in advance of the main South African crop and sold in European markets at substantial price premiums.

In areas with only a single annual rainy season, the irrigation of annual crops may allow the number of crops produced per year to be raised from one to two, and exceptionally to three. However, this depends on the time that the main crop takes to mature and the existence of viable crops for the potentially less productive new second season. In central Kenya, it has proved possible to grow two crops per year of the local Sindano variety of rice but only one crop of the higher-valued Basmati variety, which has a longer growing season. In general, there is a greater possibility of growing multiple crops at low latitudes where there is no distinct winter season and where there is adequate sunshine and warmth for rapid vegetative growth throughout the year.

The impact on processing and marketing of the introduction of irrigated double cropping depends on the storage properties of the unprocessed crop and on whether or not the same crop is planted during the second season. If the same crop is planted in both seasons, and particularly if the crop is rapidly perishable, double cropping is likely to increase the efficiency of processing as it increases the number of months in which processing capacity can be utilized. The likelihood of the second irrigated crop being the same diminishes as one moves away from the equator.

IMPACTS ON QUALITY

A switch from rainfed to irrigated production affects the quality characteristics of the commodity produced, including size, taste, smell, visual appearance, milling characteristics, and cooking properties. It also affects the extent to which these characteristics vary within a single harvested crop and between years. In so far as irrigation leads to healthier plants, the general size and quality of the produce is likely to be higher. However, it is possible that rapid growth may diminish the intensity of flavour and smell, reducing market value.

BOX 4

The Fresh Produce Exporters Association of Kenya initiative

Since 1990, Kenyan exports of fresh fruits, vegetables and cut flowers have grown explosively. In 2002, these products accounted for some 35 per cent of national agricultural export earnings. Kenya is now the second largest horticultural exporter in sub-Saharan Africa, after South Africa, and the second largest exporter of vegetables to the EU, after Morocco. Nationally, the value of horticultural exports have overtaken that of coffee and is now second only to tea.

Some 40 per cent of Kenya's fresh horticultural exports are sold to United Kingdom (UK) supermarkets and the majority of the remainder to UK wholesalers and to other European countries. Fresh fruit and vegetable exports comprise principally French beans and so-called Asian vegetables, with smaller amounts of other vegetables and fresh fruits.

Exports, especially to UK supermarkets, are characterized by high and constantly changing standards and by demand for new varieties and new forms of processing and presentation. Supermarkets in particular also now specify conditions relating to the conditions under which the products are grown and processed, including minimum agronomic and labour standards. This requires that each unit of output be traceable back to its origin.

To respond to these stringent and demanding conditions, a marketing system has developed that is driven by buyers in developed importing countries and is markedly different from the systems that have developed for the marketing of grains in Ethiopia and in other sub-Saharan Africa countries, including Kenya. The major supermarket groups work with a small number of specialized importing firms that acquire consignments from a relatively small number of specialized exporters. Some of these exporters have ownership linkages with importing firms, some have their own packhouses and some own their own farms. Small-scale farmers have been progressively squeezed from the industry and about 25 large farms now account for some 75 per cent of total exports. The small-scale producers that remain operate on a contract-farming basis with exporters who supply them with both inputs and credit and advice. In the case of fruits and vegetables retailed by European supermarkets, most are grown to order with prices at each point in the marketing chain being pre-agreed rather than determined by market forces at the time of delivery. To meet and exploit the concerns of developed country buyers with 'process' as well as 'product', exporters have formed a Fresh Produce Exporters Association of Kenya (FPEAK) which, *iner alia* has developed its own minimum process standards.

The vertical coordination within the supply chain and the horizontal concentration of production, processing and marketing have developed to allow timely delivery to supermarket groups of high-quality produce of a precise and frequently changing specification produced under conditions that the groups deem acceptable. By contrast, Ethiopian grain faces much less stringent requirements. Grain is storable, poor quality grain is readily saleable, there is little change over time in the required quality of the final product, and buyers are concerned only with what they buy not how it was produced and processed.

Irrigation typically has a major beneficial impact on the uniformity of the crop both between growers and over time. The main increase in uniformity is usually between years as under irrigation similar amounts of water can be applied on a timely basis each year. This contrasts with rainfed agriculture, where the timing and intensity of rainfall often varies markedly between years. Between farms, the introduction of irrigation into an area has the potential to lead to increased uniformity of the crop within that area to the extent that farmers under the former rainfed regime planted at different times or received different amounts of rainfall. However, this increased uniformity is dependent on equitable distribution of irrigation water between farmers, which is not always achieved.

Another advantage stemming from increased planting-date uniformity under irrigation results from decreased accumulation of stage-dependent pests and pathogens. This is because populations of such pests and pathogens are not given the opportunity to expand by moving from plot to plot where excessively staggered planting provides ideal conditions for longer.

Within an individual field, the contribution of irrigation to uniformity is likely to be minimal as all parts are likely to receive similar amounts of water under a rainfed regime. Indeed, it is possible for irrigation to lead to a less-uniform application of water within fields, as is often the case under furrow irrigation.

In summary, the introduction of irrigation most commonly improves the overall level of quality and leads to less variation in quality between producers and between years. Reduced quality variation between producers serves to increase the efficiency of processing, especially where machinery is set for a specific standard of raw material, as is the case for most agricultural processing, particularly that involving milling. Reduced quality variation between years leads to two marketing benefits. First, it allows a set of irrigated farmers or an irrigated estate to develop a reputation for a particular quality of produce that attracts regular customers prepared to pay a premium price for dependable quality. Second, it assists producers to predict the quality of their crop. This helps them to sell forward with confidence and to lock into an assured producer price prior to harvest. Box 4 presents an illustration of this impact.

IMPACTS ON THE STABILITY AND PREDICTABILITY OF PRODUCTION

Income stability is particularly important for small-scale producing households. This is because they typically lack the capacity to save and normally cannot borrow other than informally at very high rates of interest. This means that they are unable to moderate the impact of income instability on household expenditure. Consequently, they face severe hardship when income falls.

The introduction of irrigation not only increases the level of crop output but also increases the stability of output from year to year. This tends to have a stabilizing impact on producer incomes, especially for internationally tradable commodities whose domestic prices are a function of international prices. For low-value perishable commodities, for which markets clear domestically, quantity and price movements tend to be offsetting. This moderates income instability in situations where common weather patterns affect the output of growers. Once irrigation is introduced for such commodities, output comprises stable irrigated production and unstable rainfed production. In this situation, the irrigated production reduces aggregate domestic instability in supply and prices. This in turn partially stabilizes the incomes of rainfed producers, provided demand for the commodity is price inelastic. The necessary degree of price inelasticity to lead to more stable gross incomes for rainfed producers increases as the share of irrigated output increases. Conversely, in such market circumstances, instability in rainfed production will always destabilize the gross incomes of irrigated producers unless irrigated output is for some reason unstable and correlated with rainfed output.

The generally stabilizing impact of the introduction of irrigation on farm household incomes stems from its effect on the stability of yield of a specific crop that was being grown previously under rainfed conditions. Should irrigation result in a switch of crops, it is conceivable that yields of the new irrigated crop may be less stable than the former rainfed crop. It is also possible that a switch to irrigated production may result in the growing of a crop for which prices tend to be less stable than those of the former crop.

The stabilization of production has the important additional advantage of improving the accuracy with which producers can predict their output in advance of the production season. As with improvements to the consistency of quality, this increases their ability to sell forward and to enter into long-term contractual arrangements with input suppliers/processors. This in turn allows them to lock into a price in advance of the harvest and to eliminate price risk.

In summary, the introduction of irrigation tends to reduce the risks facing producers by reducing the instability and improving the predictability of both yields and producer prices. As noted above, it also tends to improve and increase the predictability of quality. Together, these effects have the potential to improve the welfare of producers and to increase the net benefits from investing in irrigation.

OTHER SOCIAL IMPACTS

The predictability of quality and output as discussed above could arguably be described as social impacts, but there are more as Box 5 illustrates..

First, there is the income stability that better predictability brings as does the ability to diversify and thereby hedge against both market and climate shocks. This helps with household or group financial planning, and it also makes credit more manageable. It could also make credit more accessible, thereby facilitating further increases in production. Diversification also means that higher-value crops and crops with significant seasonal niche markets and/or added-value opportunities can often replace former subsistence systems, thereby allowing poor households better access to the local and national economies. Added-value opportunities often include grading, processing and packaging, many of which can be carried out within the farm or scheme boundary, thereby raising incomes significantly. As well as creating more on-farm jobs, the same measures increase the need for direct and indirect services concerned with the basic agricultural activity. Direct services might include cold-storage construction and operation, transportation, freight consolidation and the manufacturing and supply of packaging material and farm inputs. Indirect services are those associated with an economic growth point and are supplied by a broadening range of local artisanal skills, retail trade and equipment maintenance capacity.

Finally, irrigation is beneficial also because it makes it easier to keep urban costs of basic commodities at affordable levels.

However, when the supply of commodities increases, prices are likely to fall especially when shortfalls requiring imports are replaced by surpluses looking for a place in regional or global markets. Although it has been argued that adequately informed dynamic pricing capability is in place and sufficient to contain the more extreme results of price reductions, there will nonetheless be a detrimental effect on rainfed producers of the same commodities and the rural landless, further marginalizing them. This is especially the case the further such producers are from the employment opportunities represented by successful irrigation. Equally, ill-conceived or inflexible institutional measures have the potential to bankrupt farmer groups and their members, even where productivity is both efficient and high. This is especially risky where production becomes more specialized and dependent on inputs, monopolistic markets and rent-seeking creditors and intermediaries. This situation is not helped by the fact that irrigated production is often subsidized (e.g. by low recurring-cost recovery) whereas rainfed farming seldom is.

BOX 5

The impact of irrigation on poverty: a case-study from the Gambia

Von Braun *et al.* (1989) studied a new rice irrigation project involving 7 500 farmers in The Gambia. The technology was in the form of mechanical pump irrigation and improved drainage for rainfed and tidal irrigation. Its expansion pulled labour away from other crops, reducing output of the latter, but increasing net calorie production overall. The project was likely to benefit excess farm-household or landless labour since 24 percent of the work is carried out by hired labour which played a marginal role in rice production before the project. Average labour productivity was greatest in the fully water-controlled rice fields (ones with pump irrigation). In partly water-controlled fields (tidal irrigation or improved rain-fed cultivation and drainage) labour productivity was only half of that in the fully water-controlled, though 30 percent higher than that in swamp rice.

At the sample average, the irrigation project increased real incomes by 13 percent per household. Moreover, since rice production contributed 43 percent of per adult equivalent income to the bottom income quartile and 26 percent to the top quartile, poor households gained disproportionately, and thus the new rice technology contributed to a more equal distribution of income in the area (at least in the short run). However, the study predicts that the poorest are also likely to be most adversely affected in case there is deterioration in project yields. The gains to household income raised calorie consumption, in turn improving the nutritional status of children. Mothers' weight loss in the wet season, not only a health and nutrition problem for them but also indirectly for the children as it relates to low birth weight, was found to be reduced with increased access to the new rice land. Unfortunately without supplementary programs for child-support, the greater the access to the rice project, the more frequently mothers took their smallest children with them to the swamps, which increased their susceptibility to disease.

The introduction of the new technology led to a transformation of the status of rice, traditionally a women's crop grown to a large extent on private farms, to communal crop under the authority of the male compound head. Thus female farmers, despite being previously allocated formal land titles, now controlled only 10 percent of their pump-irrigated plots. This change increased the burden of communal agricultural work disproportionately for women (though men's burden increased also), reducing women's opportunity to grow private cash crops and receive independent incomes, as well as limiting the beneficial calorie consumption effect of higher household income. However, women were not necessarily dispossessed of all individual farming rights or of an independent income. They organized private production of upland crops (such as groundnuts and cotton) and many were paid for work on the new rice fields by the compound head

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ENVIRONMENTAL IMPACT

The literature on the environmental impacts of irrigation in sub-Saharan Africa is extensive from Cameroon (Loth, 2004), Zambia (Jeffery *et al.*, 1992).

Although there are environmental benefits that accrue to irrigation (e.g. paddy fields can provide havens for migrating wetland birds), the costs trend to out-weigh the benefits particularly if schemes are poorly operated. If irrigation is to be justified, these costs need to be internalized by the irrigation scheme or mitigated through alternative agricultural practice and hydraulic design (Box 6).

As explained above, at the macrolevel, undeveloped land and water resources are large in relation to irrigation development potential. However, this comment needs qualification. For example, in Zambia, national-level water resources are large in relation to the country's irrigated area, yet in many areas where water is used for irrigation, there is considerable and increasing competition for it. Although this is

BOX 6

Environmental Solutions from the World Wide Fund for Nature

With ZESCO and MEWD, WWF is working to improve the management of water resources in the Flats by improving the operating procedures of the Kafue Gorge and Itezhi-tezhi Dams. The aim is to mimic natural water flows as closely as possible in order to restore wetland functions and values. The first phase of this partnership produced an Integrated Water Resources Management Strategy, which has since been accepted by all stakeholders. Computer models were also developed to simulate potential water management scenarios and to study their likely impacts. The second phase began in July 2003 and, over nine months, will focus on implementation of the new water management system for Kafue Flats. Re-establishment of the hydro-meteorological monitoring network, further refinement of computer models, dam operation, and legal and institutional frameworks are the main components of this phase. Testing of the new dam operating procedures is expected by early 2004, with the hope that the Zambian government will take a positive decision to commence the new system during 2004. All key stakeholders and water users are part of this process. The Integrated Water Resource Management project is part of the Kafue pilot project being implemented by the Ministry of Energy and Water Development through the Water Resources Action Programme (WRAP). WRAP is trying to develop a national strategy that will improve the management of water resources (surface and groundwater) throughout Zambia. It is hoped that this groundbreaking project will act as an example and catalyst for sustainable water resources management in the whole region, notably the wider Zambezi River basin.

Extract from: Case study on river management: Kafue Flats.
http://www.panda.org/about_wwf/what_we_do/freshwater/our_solutions/rivers/irbm/cases/kafue_river_case_study/index.cfm

largely a regulatory matter, the example does indicate the important difference between resource requirements at the macrolevel and microlevels (FAO, 2002).

The wide range of environmental risks associated with irrigation and the bulk storage facilities required in order to secure the necessary water resources are widely reported and are only listed here (Table 16).

TABLE 16

Environmental risks associated with irrigated agriculture

Quality	Health	Quantity	Ecology
• pollution of surface water and groundwater due to excessive chemical applications • reduced absorptive capacity of natural streams • unnaturally high turbidity levels and sedimentation in wetlands and coral reefs	• increase of water-related vector-borne disease • skin problems arising from high chemical loads	• attenuated flood and turbidity cycles leading to disrupted marine food chains which begin at the brackish margins • ditto freshwater wetlands, which can have great economic and cultural significance • reduced environmental stream flows • unsustainable lowering of water tables and associated reductions in flows at seeps and springs • increased intensity of flooding as a result of scheme drainage	• habitat loss • habitat conversion • lost biodiversity • fragmented water bodies and compromised gene-pool integrity of freshwater species including capture fish stocks • waterlogging and breakdown of soil microbial activity • soil deterioration • increased greenhouse gasses • disrupted migratory routes • disrupted floodplain functions