Policies, Institutions and Market Development to Accelerate Technological Change in the Semiarid Zones of Sub-Saharan Africa

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Abstract

Agriculture in the African dry lands is constrained by geographical and economic isolation due to limited market access which affect adoption of new technology. International subsidies that flood developing-world markets with cheap food, national policies that tax the agricultural sector to benefit urban interests, and neglect of rural infrastructure discourage agricultural intensification. Increased market demand for staples and for higher-value products produced more efficiently will ensure that dryland farmers realize an economic gain from adopting more intensive practices. The interdependence of these key factors requires an integrated management of water soil fertility and improved crop varieties research focused on the poor, particularly women and children to ensure that they are equipped to capture most of the benefits of these changes. Low-value but essential food security crops need public sector assistance until their intensification becomes attractive to the private sector. Drought and market risks determine farmers' decision-making in the drylands; yet it is too often assumed that new technology increases risk. Some technologies, policies and institutions can reduce risk.

Drought risk can be combated through water harvesting, improved soil physical conditions and efficient supplementary irrigation where cost-effective. Nutrient use efficiency can be enhanced by correcting the most-limiting deficiencies, placing fertilizers directly in the root zone, combining inorganic with organic sources and adjusting topdressings to climatic conditions. Once these risks are reduced, gains from more input-responsive, longer-season varieties can be realized. Postharvest risk can be reduced and incomes increased through cooperative grain storage, inventory credit, improved processing and marketing systems, as well as diversification into new crops, crop products and related enterprises

Key words: Diversification, drought, risk, intensification, nutrient use efficiency, water harvesting, water use efficiency

Introduction

Technological change has been the main source of increased agricultural productivity throughout history (Sachs, 2002). However, markets, policies, institutions, and infrastructure have largely determined adoption of improved technologies Most of Africa's dryland area is far from coastal ports and their urban centers. These areas are ecologically and culturally distinctive, including the over-arching threat of drought. Most of the poor in the drylands work in agriculture, but subsidized food imports and poor input and marketing infrastructure render these areas less competitive, discouraging agricultural intensification (McCalla, 2002). There is global concern that the drylands are being left behind, becoming mired in persistent poverty and conflict.

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This paper explores how productivity might be increased in dryland sub-Saharan Africa through an integrated genetic and natural resource management approach.

Are poverty and degradation inevitable in the drylands?

It has been suggested that poverty, overpopulation and land degradation create a self-reinforcing downward spiral leading to ever-greater misery (Cleaver and Schreiber, 1994). This scenario contrasts with the 'induced innovation' model of Boserup (1965), which proposes the opposite dynamic. The induced innovation model suggests that as populations grow, markets tend to develop and land becomes more costly relative to labor. These factors motivate investment in more intensive, yet sustainable land management in order to reap the benefits of the enlarged market opportunity.

Both scenarios have been observed under different situations (Pender, 1998). There are numerous pitfalls that can occur along the induced innovation pathway. Larger populations can result in more people sharing the same pie rather than a bigger pie. Farm wages are only likely to increase if crops are produced more labor-efficiently than before. This is where new technologies come into play (Hazell and Haddad, 2001; Pender, 1998). Technologies such as irrigation, fertilizer and improved varieties have been available for a long time, but their adoption has been limited due to a number of interdependent constraints.

Risk and new technology adoption

Dryland farming is inherently risky due to drought. Smallholders have only limited means for financially cushioning against risk, such as off-farm employment, family networks, and moneylenders (Anderson, 2001). Though it is often assumed that new technology increases risk, and that farmers are unwilling to take risks, these assumptions have been questioned for the Sahel (Sanders et al., 1996). Improved water management practices, the correction of certain nutrient deficiencies, and shorter-duration varieties that escape drought all reduce risk or do not increase it significantly. Smallholder farmers appear willing to take considered risks, particularly when they have had the chance to see and try a new technology and gained confidence that it will succeed (Sanders et al., 1996; Abdoulaye and Sanders, 2005; Tiffen, 2002, 2003; Mortimore and Harris, 2004; Sanders and Shapiro, 2006).

Water availability and water use efficiency

Drought is a constant risk the drylands. Little can be done to prevent variations in rainfall. Yet more can be done to reduce drought *vulnerability* than is commonly assumed. Due to limited vegetative cover, sandy soils, and root growth limited by nutrient constraints, much of the rain that falls in the drylands either runs off or percolates below the root zone (Wood and Rydén, 1992; Breman, 1992). Breman (1992) noted that natural vegetation in the 450 mm annual rainfall zone of the Sahel utilizes only 15% of the incident precipitation and when soil physical condition and fertility are improved, water use by vegetation increased to 50% and productivity can increase fivefold.

Water harvesting and conservation technologies can reduce losses. Proven techniques developed by farmers include bunds, trenches and terraces on the slopes of the Ethiopian Highlands (Krüger et al., 1996); bunds and furrows to channel water and nutrients in Sudan (Niemeijer, 1999); zaï holes to hold water and manure in the root zone to rehabilitate eroded hardpan soils in Burkina Faso (Kaboré and Reij, 2004; Ouedraogo and Kaboré, 1996); and tied ridges in Mali (Sanders and Shapiro, 2003; Vitale and Sanders, 2005).

Irrigation in Africa has gotten a bad name due to the failure of large-scale projects. This has caused many to overlook the enormous potential that exists for smallholder irrigation (Kay, 2001). Even in the drylands, large numbers of farmers have access to shallow groundwater tables in river drainage basins. Smallholder irrigation is likely to be economically attractive mainly for high-value crops in reasonable proximity to urban markets. In such situations it has substantially raised farm incomes, as in the areas around Sokoto and Kano, Nigeria (World Bank, 1995) and in the Koumadougou Valley in eastern Niger (IFAD, 1999).

Though laborious or costly to implement, water conservation, harvesting and irrigation techniques deliver attractive returns on investment and substantially reduce risk (Sanders et al., 1996; Shapiro and Sanders, 1998, 2002). The fact that farmers are using them on a significant scale already is evidence of their practicality, although ways should be sought to accelerate their spread. Often these structures can be established during the dry season when labor is readily available.

Soil fertility, fertilizer and risk

Soil nutrient deficiencies are widespread in the drylands. In much of the Sahel it is a more important constraint than low rainfall (Bationo and Buerkert, 2001; Breman, 1992). Dry and hot conditions limit vegetative growth, resulting in low soil organic matter content compared to wetter environments. Human activities exacerbate this problem. Vegetation is often removed for fuel, feed and construction purposes, instead of recycling into the soil. Soils that are low in organic matter are less effective in retaining nutrients in plant-available forms and are more susceptible to compaction and erosion. This drives organic matter and nutrient contents even lower, depressing productivity further.

Fertilizer can increase dryland productivity significantly when rainfall is adequate, but many believe that it creates unacceptable levels of risk for dryland smallholders. Recent evidence though shows that in some situations it may be risk-neutral or even risk-reducing. Phosphorus causes crops to grow hardier and mature earlier, reducing damage from and exposure to drought (Gérard et al., 2001; ICRISAT, 1985–88; Sanders et al., 1996; Shapiro and Sanders, 1998; Shapiro et al., 1993).

Once the phosphorus constraint is relieved, increased crop growth soon exhausts available supplies of nitrogen – so both P and N enhancement strategies are required. Nitrogen amendments appear to incur greater risk than phosphorous since N is not drought-protective; drought can prevent the expected yield response, leaving farmers with a loss on their N investment. Therefore, improvements in soil moisture should be implemented along with N (Shapiro and Sanders, 1998; Sanders et al., 1996). One coping technique is to split the N application between planting and tillering stages, with the second application being conditional on favorable rainfall patterns.

Some fertilizers pose risks to soil health in dryland situations. Because of low organic matter and low cation exchange capacity many Sahelian soils are weakly buffered, raising the risk of soil acidification through the use of ammonium-based fertilizers (Bationo and Buerkert, 2001). The addition of organic matter such as livestock manure remarkably moderates these effects, but these areas are not capable of producing enough manure to meet the need (Breman, 1992). Inorganic fertilizers will be needed as complements to organic sources, but they must be introduced in ways that do not undermine soil health.

Triggering a self-reinforcing cycle of fertilizer use

Farmers have been mostly unable to implement research station fertilizer recommendations because the high rates being urged were unaffordable, risky and of questionable profitability in addition to constraints in market access, infrastructure, and liquidity. Researchers are investigating whether reducing the amount of applied fertilizer well below historical recommendation levels and placing it in the immediate root zone might help mitigate some of these problems. Phosphorus has been a focus of these studies because it is a limiting constraint in many areas of the Sahel. Government-recommended rates of 13 kg P/ha in Niger were cut to roughly one-twentieth to one-fourth of that in these experiments.

This technique is called ‘microdosing’ (Aune et al., 2004; Gérard et al., 2001). By placing the fertilizer in the planting hole, it is co-located with the main root mass early in the season, apparently resulting in a more efficient nutrient uptake. Microdosing reduces the farmer’s cash outlay while increasing the efficiency of cash use (return on investment). Low rates also reduce the soil health risk. Although the response to microdosing varies significantly across locations, across different soil types, field histories, and fertilizer formulations, it commonly increases yields by 50–100% on typical smallholder farms.

The benefit/cost ratio (value of additional grain divided by cost of fertilizer to obtain that grain) is a useful rule of thumb in assessing likely adoptability. A value above 3 is generally considered attractive enough to spur adoption. In farmer’s sorghum fields in Bafaloubé, Mali in 2002, Aune et al. (2005) applied 0.6 kg P/ha with the microdosing technique and the yield response resulted in a very attractive benefit–cost ratio of 12.4. Across 150 farmer’s field trials in Sadore, Karabedji and Gaya in Niger, Bationo (unpublished data) applied 4 kg P/ha delivering a benefit–cost ratio of 9 when fertilizer cost is double the value of the same weight of millet. Equally impressive responses have been observed on maize in dryland areas in Zimbabwe, with a 10:1 benefit/cost ratio (Dimes et al., 2006). Some though have obtained less dramatic results (Gérard et al., 2001).

It appears that microdosing can be economically rewarding in many nutrient-depleted situations. Major efforts are underway to disseminate this technology. Food Agriculture Organization (FAO) is sponsoring 'Projet Intrants' which has conducted hundreds of demonstrations across Niger. With DFID support, ICRISAT and Zimbabwe are distributing seed and ammonium nitrate with microdosing instructions (apply at one-quarter the former recommended rate per hectare) to 160,000 farm families.

Since most dryland farmers are starting from a very low yield base of around half a ton of cereal grain per hectare, there is room for even greater yield gains than those generated by microdosing. Higher fertilizer rates combined with better water supply can move yields into the 2-ton range while reducing risk (Sanders and Shapiro, 2003). Although the high benefit–cost ratios for microdosing decrease as fertilizer rates increase, higher rates are still profitable (Sanders et al., 1996).

Microdosing might trigger a process of increasing fertilizer use that becomes self-reinforcing over time. As fertilizer stimulates the growth of more crop biomass than is needed for human and livestock purposes, the excess would add to soil organic matter reserves. Higher soil organic matter would improve plant growth and fertilizer response the next season. Improved plant growth would generate larger responses from improved varieties, motivating their adoption. These increasing gains could create a self-reinforcing cycle (Bationo and Buerkert, 2001; Shapiro and Sanders, 1998). This gradual intensification could allow farmers to observe, learn and adjust their practices and resources in ways that are more sustainable for the longer term than approaches that jump in one step from subsistence to high levels of production.

Integrating improved varieties into the system

If nutrients and water are adequate, more responsive varieties can markedly elevate yields in the drylands as elsewhere (Sanders et al., 1996). These varieties have had little impact to date because those conditions have not been in place (Ahmed et al., 2000).

Under the existing low-input, subsistence scenario, crop improvement has succeeded in reducing late-season drought risk by breeding for early maturity. While this objective can contribute to food security and help capture higher early-market prices, it puts a limit on potential yield gains (Sanders and Shapiro, 2006). Varieties must also be made available that enhance the rewards farmers receive from intensifying production.

Stabilizing and expanding markets for low-value staple crops

Productivity-enhancing interventions will only attract farmers if they are confident that they can sell their grains for a profit. The grain crops of the African drylands, millet and sorghum are not traded internationally so the local market is easily glutted, causing farm prices to crash – followed by shortages and rising prices a few months later. Governments often attempt to stabilize prices by purchasing grain and releasing it into the market later, but many operational shortcomings have been experienced in this approach. Smallholder-run storage systems appear to hold greater promise.

Urban tastes are changing with cheap imported grains like wheat and rice. A major reason is their ease of preparation. Research could find ways that local grains could be processed, conserved and marketed, thus claiming back these urban markets for locally-grown grains (Sanders and Shapiro, 2003, 2006). Livestock feed is another major opportunity. Increasing consumption of meat in the coming decades is expected to increase the demand for animal feed; this could increase the demand for dryland grain crops if varieties and handling methods are optimized for this purpose.

Farmers often sell grains immediately after harvest at low prices in order to meet more immediate demands. In Niger, pilot studies by FAO and partners are testing an 'inventory credit' approach They ask farmers to place grain in collective stores; loans are issued with the grain as collateral to meet farmer's immediate cash needs. Farmers get additional cash later when the grain is sold at higher prices. This increases their profits from grain farming, and thereby raises their incentive for increasing production through the adoption of new technologies such as water control, fertilizer and improved varieties.

Diversification into higher-value crops and products

Other ways to increase farming income are to grow higher-value crops, and/or create higher-value products from traditional or new crops. Many have advocated diversification to open new income-earning opportunities (Hazell and Haddad, 2001; Leakey et al., 1999;

Ndikumana et al., 2002; Pasternak and Schlissel, 2001; Tengberg and Stocking, 2001). In addition to alleviating poverty, more diverse and profitable crops and crop products encourage farmers to improve soil fertility and water control and adopt improved varieties, as the well-known story of Machakos, Kenya demonstrated (Tiffen et al., 1994).This also stimulates diversification in related agro-enterprises, creating a ripple effect that multiplies the benefits broadly through rural communities (Hazell and Haddad, 2001).

In addition to satisfying local urban demand, specialty crops can tap foreign markets to earn foreign currency for the poor. For export markets though, the entire production, processing, handling and marketing chain must be efficient since international markets demand consistent, high and uniform quality and dependable supplies. The private sector will be essential for linking into international markets, but public sector agencies and NGOs are playing important roles in catalyzing these partnerships, organizing the poor so they produce a reliable stream of sufficient product volume, and ensuring that the poor garner a fair share of the benefits.

Integrating genetic and natural resource management

Water responses are dependent on soil fertility, and vice-versa. Improved variety responses are dependent on both. Market demand and access, and pro-poor policies are required for motivating farmers to seek these responses in the first place. Therefore, an integrated approach to simultaneously alleviate these constraints is essential. A major reason for past failures has been a focus on just one particular intervention or another corresponding to the disciplinary competence of the intervening agency. For integration, broader partnerships are required to bring in a wider range of expertise and farmer participation is critical so that solutions are relevant and adoptable. This process makes research and development more complex.

Subsistence and commercial production perspectives

Subsistence agriculture is important for farmer's food security while commercial production provides the path towards reducing poverty and increasing national food supplies. While conceptually separate, these systems are operationally interlaced. Farmers often do some of each within their farm, and the proportion may change over time and space. Rather than emphasizing just one or the other, an integrated approach looks holistically at farmer's needs and realizes that both operations are important and require appropriate technology options.

Agricultural development in Africa requires an increasing proportion of commercial systems over time in order to meet growing food needs as well as to reduce rural poverty. The public sector needs to provide continuing assistance on subsistence systems, since those systems offer little opportunity to the private sector. For example, improved seeds of staple grain crops may not be profitable in a subsistence context, but are important for stimulating a transition to more intensive systems (Sanders and Shapiro, 2006). Small-scale machinery such as tied-ridge makers and shallow bore well equipment can advance water management, but often require initial sponsorship and public policies that encourage rural village entrepreneurism (Shapiro and Sanders, 1998). In short, both public and private sectors need to work closely together to foster the gradual transition from subsistence to commercial systems.

Conclusions

The key constraints to technology adoption and agricultural development in drylands relate to in soil fertility, water, crop genetics, and markets. However, integrated genetic and natural resource management approaches have often been lacking in the past. Approaches such as small-scale water conservation/harvesting, fertilizer microdosing, longer-duration varieties, inventory credit management and crop/product diversification for transitioning from subsistence to commercial production are proposed to address the problem. Smallholder-appropriate interventions are more adoptable and could lead to greater progress over time as incremental gains deliver ever-greater farm profitability and therefore stimulate subsequent rounds of increasing investment. They are also more equitable because they are more accessible to the poorest farmers. Both public and private sector engagement are required for success, with the former taking the lead in subsistence agro-ecosystems and the latter assisting farmers as they transition towards commercial systems.

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