New Financial Instruments to Help Improve Agricultural Water Management for Poor Farmers Under Conditions of Risk

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Financial instruments can help alleviate poverty through better agricultural water management

Using examples of drought insurance, payment for environmental services and warehouse receipts, this brief paper discusses the potential roles of some new financial instruments to support agricultural water management in rainfed areas of developing countries. In so doing, we aim to raise awareness of the broader potentials for financial instruments to improve water productivity and so help achieve two goals: alleviation of poverty that is caused by the inability of individuals to manage water, and improved water productivity that is necessary to solve an emerging problem of global water scarcity.

We discuss these issues in the following sequence. First we review the need to improve water productivity at both a global and individual level, highlighting the obstacles to improvement posed by uncertainty and risk. We then focus on a particular approach to pro-poor risk management using drought insurance, before examining briefly how two other financial instruments: payment for ecosystem services and warehouse receipts also contribute to improved water management. Finally we review some potentials and pitfalls of using the instruments.

Need for improved agricultural water management

Uncertainty and risk obstruct improved water management.

Molden *et al.* (2003) estimate that by 2020 approximately 75% of the world's population will live in areas experiencing physical or economic water scarcity. Most of these areas happen to be where most of the poor and food-insecure people live. It is widely accepted that the water productivity of agricultural production systems must increase to meet the demand for more food, while at the same time satisfying competing demands for industry, urban and environmental function.

While many strategies exist to improve water productivity (WP), adoption rates remain low. The reasons are many. Reliable, low-cost supplies of sufficient water enable high levels of productivity and reduce risk, so why should producers voluntarily reduce water inputs? Even though society at large or river basin managers trying to allocate limited supplies both have a high incentive for agriculture to deplete less water, producers themselves have little incentive.

These complex factors can be organized according to the types of uncertainty related to water productivity:

The first is the uncertainty regarding the scale of potential benefits that might accrue from increased WP. Until decision makers are clear about the specific degree, timing and cost of potential improvement in WP, the prospects for concerted effort seem limited. Who stands to gain from improved WP? Who are the winners and losers in any proposed redistribution of the water saved? What are the risks of changing WP, for example through loss of 'non-productive' environmental flows?

Surprisingly few detailed measurements exist of current WP on which to gauge the scope for improvement. Nor is it clear how variation of *potential* WP, which expresses the upper limit of gain, varies spatially. The uncertainty regarding potential benefits can be removed by gaining insights through continued measurement and analysis.

The second type of uncertainty concerns the practical likelihood of increasing WP in relation to other factors that influence decisions taken at the management level. Farmers and other water managers consider a wide range of factors in making such decisions; unfortunately, WP *per se* is unlikely to be prominent amongst them. More significant are the perceptions of risk in relation to possible returns and the incentives and support structures for measures that enhance WP.

Poverty impacts of risk

We use drought insurance to illustrate the application of financial instruments to handle the intersecting interests of risk and water management.

Agriculture is inherently risky. Exposure to risk is widely correlated with poverty (Bird *et al.*, 2002). Risk is therefore a major modifiable reason for chronic poverty. Production risks include climatic hazard, which of all the risks agriculture faces is perhaps the most difficult one for farmers to manage. Drought is the most serious threat to livelihoods globally, accounting for 44% of reported deaths in the period 1974-2003 (EM-DAT, 2004).

Droughts cause food and income insecurity through both acute effects and chronic secondary effects. Acute effects are immediate crop failure, which in extreme cases leads to hunger and even starvation. Secondary consequences of drought include increases in local rates of interest due to an increase in the number of households seeking credit and a decline in the demand for farm labor leading to a reduction in local wages due to greater numbers seeking off-farm employment. Livestock also suffer hunger and starvation leading to falling prices due to distress sales. Food prices increase coincidental with falling financial resources available to rural households as sources of income dry up (Sakurai and Reardon, 1997). Nearly 80% of farmers interviewed in Ethiopia cited harvest failure caused by drought and other natural hazards as the event that caused them most concern (Dercon, 2001). Pandey *et al*. (2001) revealed a huge drop in income for rice farmers in Orissa state in India as a result of drought. This work is substantiated further by experience from more recent droughts in the region.

The mere expectation of drought is sufficient in some cases to reduce agricultural production, through its impact on investments that would otherwise increase productivity. Farmers, who are characterized predominantly as being risk-averse, are reluctant to invest in the face of significant uncertainty.

Impacts of risk on agricultural water productivity

Informal risk-coping mechanisms (table 1) that predominate in developing countries not only present a barrier to improved productivity but reinforce the situations which reduce it (Barrett *et al*., 2001; Brown and Churchill, 1999; Rosenzweig and Binswanger, 1993). They do this because firstly they reduce resource use efficiency and secondly they avoid investments that in the long term would increase productivity (Hazell *et al*., 2000; World Bank, 2001). For example, widespread experience from the Sahel region shows that faced with the possibility of drought, farmers apply fertilizer at rates well below the optimum, (Bationo and Mokwyunye, 1991) because the additional investment increases their loss should the crop fail.

In addition to direct loss of water productivity caused by individuals risk-coping behaviour, knock-on effects reduce the productivity of the entire system. Hussain *et al.* (2001) point out the importance of multiplier effects, through food security and income generation Informal insurance is ineffective to cope with widespread, covariate risk events such as drought. Repeated shocks further undermine it (Dercon, 2003). A survey in India found that 30% of respondents cited loss of wages, income or work as a major impact of a risk event (Hess, 2003*a*). Financial institutions are unwilling to lend to such borrowers precisely because of their vulnerability to drought risk and the consequential likelihood of default on loan repayments (Hess, 2003*a*). Indian banks, who lend to farmers in irrigated areas, are constrained by the risk of drought from extending credit to farmers in nonirrigated areas (Mishra, 1994).

About 80% of the population of Ethiopia depends on rainfed agriculture for subsistence. Agricultural production and GDP is highly correlated with variation of rainfall around the average. McCarthy *et al.* (2004) show that, for pastoralists at least, the coping mechanisms of mobility and flexibility are used mainly to deal with uncertainty. Further analysis suggests that climate variability, principally variations in rainfall, costs the economy over one third of its growth potential (World Bank 2006). The potential gains of improving agricultural WP under these circumstances seem substantial. Rockström (2003) estimates that gains in WP of 4800 km^3/yr will be required from rainfed agriculture to meet demand in 2050. There is some optimism that this can be achieved as shown by the substantial gaps between actual and potential crop yield (Rockström and Barron, 2003). Large gains in crop yield appear achievable in Africa through investment in fertilizer to correct the widespread depletion of soil nutrients, but those yield gains are vulnerable to even short dry spells during the ‘normal’ growing season (Christianson *et al*., 1990; Bationo, 1989).

Drought insurance as a means of improving agricultural water management

Farmers use a range of measures to cope with risk. Table 1 identifies informal and instrument-based measures of risk avoidance used in farming.

Table 1. Risk management tools

Self-insurance measures	**Modern risk-avoidance measures**
Crop diversification	Production contracting
Maintaining financial reserves	Marketing contracting
Reliance on off-farm employment	Forward pricing
Other off-farm income generation	Futures options contracts
Selling family assets (e.g. cattle)	Leasing inputs
Avoidance of investments in expensive processes such as fertilizing (especially in high-risk years)	Invest in fertilizer, use long-term forecasts
Accumulation of stocks in good years	Acquiring crop and revenue insurance
Removal of children from education to work on farm	Custom hiring

(Source: Wenner and Arias, 2003; Skees *et al.*, 2001; Hess, 2003)

Many argue that informal self-insurance measures are a barrier to poverty alleviation (Rosenzweig and Binswanger, 1993; Brown and Churchill, 1999; Barrett *et al*., 2001). Traditional risk-coping mechanisms not only sustain poverty but are believed to actually hinder development because risk-averse strategies generally use resources inefficiently. Additionally, they fail to exploit more productive investments and technologies that in the long term would result in more water productive systems (Hazell *et al*., 2000; World Bank, 2001). Informal measures are more widespread in developing countries because most of the modern risk-avoidance measures are not readily available in those countries. Farmers in these regions are obliged to adopt traditional informal risk-coping mechanisms, even though they are known to be sub-optimal.

Insurance is a financial instrument that enables investment through transparent sharing of risk. Drought insurance exchanges the irregular uncertainty of large losses caused by drought for regular small premium payments. A rule of thumb is that the larger the proportional loss in assets and income, the fewer alternatives there are to recover from the loss (Brown and Churchill, 1999). Insurance is one of the few viable options for poor people to manage uncertain events that can cause large losses. Other tools that lie outside the scope of this article include savings, mutual plans or credit (Brown *et al*., 2000). The reader is referred to this reference.

Two broad principles govern insurance design. The first is that risk-sharing can only occur when both parties (the insurer and insured) have accurate information about a hazard and the likelihood of it occurring. Skees (2003) maintains that a sound weather insurance product is transparent and symmetrical, so eliminating both moral hazard and adverse selection. This has been true for over three centuries. Transparency means that the basis of insurance is obvious to all parties, enabling agreement about expected wins or losses. The conditions under which payout occurs is determined by the insurer and must be evident to the insured. Symmetrical means that both parties have access to approximately the same level of information and are agreed about the level of uncertainty that remains.

The second requirement is that the risk sharing must be broad enough to avoid co-variate risk (the risk that all crops insured in a scheme are affected), given that major weather events typically have broad geographic coverage (Miranda and Glauber, 1997).

Developing low cost drought insurance

Weather micro-insurance has been proposed as a viable tool to help poor farmers manage weather risk, which translates into crop production risk. The principles behind weather insurance have been widely discussed (Skees *et al*., 2001; Bryla *et al*., 2003; Hess, 2003; Stoppa and Hess, 2003; Varangis *et al*., 2003). A review of the principles of the insurance process follows.

The basis of insurance is an agreed estimate of hazard probability (Skees, 2003). The probability of occurrence of specific events must be identified and agreed by both parties to ensure symmetry of information. The normal method of estimating these probabilities is from prior events. For the purposes of crop insurance against drought in developing countries this faces two difficulties. Firstly, accurate historical data of loss events may not exist. Secondly, data may exist but not for the population being insured.

Indices of crop yield are a relatively new method for insurance products that have been applied as area-average indices (Skees *et al.*, 2001). Indemnity payments are made to policy-holders when the area-average yield for a particular season falls below a predetermined long-term area average. The index in this case is a percentage of the long-term area average yield. Examples can be found with corn in USA, rice in India, livestock in Mongolia and pastures for beef production in Canada.

Area-average indices may not be appropriate for developing countries where long and reliable yield data are not available (Skees *et al.*, 2001). Moreover, in developing countries, yield data are normally derived from research stations, which may not be representative of the area as a whole. Research station yields are known to overestimate farmers' yields by 30% or more (Davidson, 1965). Furthermore, data for subsistence crops, and especially for farmers' fields, are almost never available

Weather index insurance is another relatively recent development, in which rainfall events, not yield, are the basis for determining indemnity payment. Historical rainfall data are far more widely available than crop yield data and are consequently more suitable as a basis for insurance in developing countries. The rainfall index expresses the specific rainfall events that are associated with a given level of crop loss. Crop sensitivity to drought incidence varies according to growth stage, precedent conditions and soil water storage capacity; it is therefore critical to establish the relationship between weather events (drought) and crop loss as accurately as possible.

A major problem facing rainfall index insurance is basis risk (Miranda and Vedenov, 2001; Skees *et al*., 2001; Turvey, 2001; World Bank, 2001; Skees, 2003). Basis risk occurs when the index does not represent actual loss: either the trigger is too heavy and fails to indemnify actual loss or payment occurs without loss. Additionally basis risk may occur when risk over a heterogeneous area is estimated from sparse rainfall data.

Other financial instruments of potential to agricultural water management

Payment for Ecosystem Services

Interest is increasing in the concept of payments for ecosystem services (PES). PES exists in a diverse array of forms as instruments to reward or compensate people who modify the environment in ways that are deemed beneficial (Figure 1). Land users can modify water flow or water quality, preserve biodiversity or modify storage capacity of (for example) soil carbon. Projects have already been initiated in Asia, Africa and Latin America. The nature of PES seems particularly well suited to agricultural water management, since it takes advantage of a fundamental feature of collective water management: people within a catchment system are connected *physically* through the water they share, but are often poorly connected *institutionally* in ways which enable improved management of the common resource.

By definition, PES schemes tend to cover large geographical areas. Also, they are likely to exchange hydrological services that may be difficult to estimate. The concept is intuitively appealing but the scale of interest currently appears to exceed the scale of activity on the ground. Swallow (2006) summarizes the main difficulties as:

- Uncertainties concerning the beneficiaries: For example, is the purpose to improve ecosystem function or to effect local improvements in well-being?
- Compensation and rewards in relation to rights, duties and uncertainties. How inclusive is the scheme? How much basis risk remains in the scheme from un-accounted events?
- Basis of agreement: outcomes, actions, plans and objectives. What is the design of the payment system, triggers, penalties, dispute resolution mechanisms?
- Uncertainties introduced by spatial and temporal variability and extent. How are intrinsic variations handled? What scope is there for modification of the agreement?
- Governance and institutions: Who manages the scheme? What is the appropriate role of state government, and what are the effects of changes in the policy and legal environment?
- Uncertainties of past and future trends. The value of a service will be affected by climate change and factors such as El Niño, demographic trends and market shifts. What are the long term benefits?

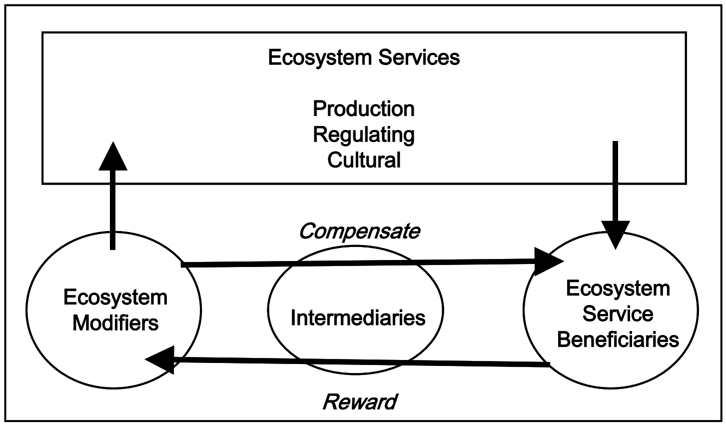

Figure 1. Overall arrangement of payment for environmental services (modified from Swallow, 2006)

Warehouse receipts or Warrantage

Warehouse receipts (WR) or warrantage systems are systems of inventory credit that provide farmers with documentation at the time of deposit of grain (Coulter, 2005). The documents enable the grain to be sold, used as collateral or withdrawn, thereby reducing the farmers' exposure to price instability while at the same time providing a timely source of credit for inputs such as fertilizer that may be necessary to take advantage of windows of opportunity for the following crop.

This instrument of WR reduces market risk more than production risk, but in so doing reduces constraints that might otherwise prevent farmers from investing in ways to increase water productivity. Tabo *et al.* (2005) report that in Niger, Burkina Faso and Mali, a project combined warrantage with a system of micro-fertilization of crops of grain sorghum or millet. The seeds were planted in "hills" (discrete planting locations, the density of which was higher where the rainfall was higher). A small amount of NPK fertilizer was applied to each hill at sowing, generally less than half the rate recommended by extension agents. The yields of sorghum and millet increased by 44 to 120% while income of farmers increased by 52 to 134% when using the fertilizer micro-dosing and warrantage compared with the earlier recommended and farmer traditional practices.

Farmer access to credit and inputs was improved substantially through the WR system and enabled farmers to finance other activities during the dry season and also to buy improved grain varieties and finance purchase of fertilizer for the coming growing season.

Potentials and pitfalls of using financial instruments to improve agricultural water management

Financial instruments promise improved water management through the following benefits:

1 Enabling investment: Investments in factors such as fertilizer, germplasm and infrastructure are necessary to maximise water productivity. Drought insurance and WR

systems enable farmers and other individuals to invest by reducing the risks caused by weather and market uncertainty. This function operates through transparent risk sharing.

2 Reduced moral hazard: A different function of financial instruments is to convey information that clarifies the correlation between specific behaviours and risks, with the intention of modifying behaviour. PES can reduce the likelihood of adverse events by rewarding upstream managers to regulate hydrologic processes to the benefit of downstream users. The drought insurance we describe can encourage farmers in vulnerable situations to avoid undue exposure to risk through the design of premium levels and the payout structure.

3 Network building: A third function is to provide transparency and stability to promote the function of networks. While insurance relies on parties independent of the water use ‘supply chain’ to share risk, the instruments of PES and WR build connectivity between actors to improve the stability and certainty of transaction.

Pitfalls

Coulter (2005), Skees *et al.*, (2001) and others provide cautionary analysis of many potential pitfalls with WR and insurance. Swallow (2006) provides analysis of the features that tend to reduce the attractiveness of PES. We attempt here to organize pre-conditions for success according to the three I’s: incentive; infrastructure and institutions.

Incentive:

The WR instrument described by Tabo *et al.* (2005) enables investment that is driven by the market for grain, without which credit may need to be subsidised below the level that is attractive to private banks. Coulter (2005) identifies the risks to private-sector based attempts to stabilise prices through WR, the alternatives to which are state intervention, and worse, by large scale public procurement.

Incentives for individuals and private companies to engage in drought insurance can be reduced by state intervention. Insurance has, to date, had an unhappy history on account of market distortions, political interference and corruption, with most failing to cover the costs of payouts (Hazell, 1992). Basis risk of insurance products can be reduced by maximising the accuracy of risk estimation. An insurance product will not be attractive to potential customers if they think that the basis risk is too high (Skees *et al*., 2001).

Most crop-insurance schemes in the past have been fatally damaged by an attempt to cover multiple perils or all-risks (Skees *et al.*, 2001). This has meant that virtually any cause of crop failure was insured, resulting in excessive indemnity payments. Because private insurance companies will not insure risks that are widely correlated, such as multiple crops, these schemes were either fully publicly-owned or had large government subsidies. Moreover, because they were all- or multiple-risk they incurred substantial moral hazard in which the insured has no incentive to take all prudent care to avoid crop losses.

Infrastructure:

Infrastructure requirements include physical infrastructure and human capital. Economies of scale seem to be an essential feature of success. Coulter (2005) observes that WR schemes started more quickly when they were initiated by large, well-capitalized farmers, close to large-scale warehouse and milling capacity, and supported by banks that were willing to provide credit. Capacity building was an essential part of the WR scheme described by Tabo *et al.*, (2005), to establish a large body of people familiar with the concepts and function of the WR system. Insurance depends on geographical scope to overcome dangers of covariate risk, through re-insurance or catastrophe bonds (known as CAT bonds, Skees, 2003). Weather insurance also may require infrastructure of monitoring stations. WR requires transportation infrastructure; insurance requires communication infrastructure to maintain transparency and information symmetry.

Institutions:

Given that deep political involvement seems to be more often unhelpful than helpful to the operation of financial instruments, Coulter (2005) comments on the value of a 'minimally supportive policy environment', to enable the private sector to operate effectively. Such an environment would provide efficient and trustworthy WR systems. Insurance has a very long history of regulation, effectively strengthened further by the need for re-insurance, to support local or regional insurers. The boundary between insurance and credit institutions is at times being blurred, and a debate is running about the merits and dangers of close association between micro-financiers and insurers. In practice, insurance is also reliant on observations from trusted independent institutions.

Conclusions:

Agricultural water management is plagued by uncertainties caused by unmanaged variations within farming systems. Uncertainties constrain the livelihood that people gain from agricultural water management, particularly in rainfed systems operating in marginal environments. Relative loss occurs because farmers, and especially poor farmers, are unable to make investments in the face of unmanaged risk. Investments include fertilizer, new seed and water infrastructure are necessary to increase productivity, which underwrites the accumulation of biological and financial capital. Knock-on effects reduce the activity of the entire farming system. A consequence of limitations within the farming system is the constraint on improving water productivity, which is necessary to meet the challenge of global water scarcity.

Financial instruments such as insurance, warrantage or payments for ecosystem services reduce the constraining uncertainty through counter-cyclic exchanges between actors in ways that are agreed to be mutually beneficial. The basis of these instruments is information about the likelihood of future events that increase certainty and help build trust.

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