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Drought Risk Reduction in Agriculture

A Review of Adaptive Strategies in East Africa and the Indo-Gangetic Plain of South Asia

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ABSTRACT

This report is a component of the Research Program on Climate Change, Agriculture, and Food Security (CCAFS)–-funded project “Impacts of Climate Extremes on Future Water and Food Security in South Asia and East Africa.” The goal of the project was to characterize extreme drought events, to improve on a methodology to assess the probability of these events in the future under climate change, to illustrate their impacts, and to provide suggestions on coping strategies. The present report sets the stage for the overall project by undertaking a review of the causes of vulnerability to drought in East Africa and the western Indo-Gangetic Plain (IGP) of South Asia, and discussing the options to increase resilience to drought in the agricultural sector. Agriculture is a high-risk endeavor in both regions, due to a combination of recurrent droughts—which may intensify due to climate change—poor soil fertility, and a host of constraints faced by farmers, especially low access to input and output markets. These factors, combined with farmers’ high aversion to risk, stifle investments in agriculture, resulting in continuous underachieving production, low income, and persisting poverty. Lack of investments leaves production prone to drought shocks and households highly susceptible to losing assets. Poverty is therefore both a determinant and a result of drought shocks. Tackling the vulnerability of farming communities is at the core of drought risk reduction and promises to reduce both poverty and food insecurity. Strategies for drought risk reduction need to encompass sustainable management of agroecological landscapes to boost agricultural production, as well as measures to improve access to food, to ensure people’s health, and to lower the risk of investment in farming. Continuous financial support is needed for development work and for investments to cultivate social capital and the capacity for disaster risk reduction across farming communities.

Keywords: drought, drought risk reduction, vulnerability, resilience, Africa south of the Sahara, East Africa, South Asia, Indo-Gangetic Plain

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ABBREVIATIONS AND ACRONYMS

AIC	Agriculture Insurance Company of India
CCAFS	Research Program on Climate Change, Agriculture, and Food Security
CGWB	Central Ground Water Board of India
DDP	Desert Development Programme (India)
DECSI	debit credit and savings institution
DPAP	Drought-Prone Areas Programme (India)
GCP	Generation Challenge Program (of CGIAR)
GDP	gross domestic product
HARITA	Horn of Africa Risk Transfer for Adaptation
IGP	Indo-Gangetic Plain
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society
IWDP	Integrated Wasteland Development Programme (India)
IWMP	Integrated Watershed Management Programme (India)
LAFCU	Lume Adama Farmers Cooperative Union
MERET	Managing Environmental Resources to Enable Transitions to More Sustainable Livelihoods
NGO	nongovernmental organization
NISCO	Nyala Insurance Share Company
NMA	National Meteorological Agency (Ethiopia)
NRAA	National Rainfed Area Authority (India)
NREGS	National Rural Employment Guarantee Scheme, Government of India
PSNP	Productive Safety Net Programme (Ethiopia)
REST	Relief Society of Tigray
RRR	repair, renovation, and restoration
SMS	short message service
SSA	Africa south of the Sahara
SWC	soil and water conservation
UNISDR	United Nations Office for Disaster Risk Reduction
WHO	World Health Organization
WUA	water user association

1. INTRODUCTION

When we think about natural disasters, the first thing that comes to mind is often loss of life. As tragic as these direct effects are, the reverberations of natural disasters can be just as bad. Natural disasters can have long-lasting negative effects on livelihoods, increase vulnerability to other shocks, and threaten long-term economic growth, therefore putting in peril future as well as hard-won development gains (Lal et al. 2012). Although losses from disasters are largest in high-income countries in absolute value, the costs relative to gross domestic product (GDP) are highest for middle- and low-income countries (Lal et al. 2012). The effects of extreme or prolonged droughts are especially hard on the agricultural sector, and for those countries whose economy relies strongly on rural agricultural production.

Drought is currently one of the main constraints for crop and livestock production in Africa south of the Sahara (SSA) and for rice cultivation across South Asia (Gibbon et al. 2007; Lal 2010; Pandey and Bhandari 2009). Drought is a complex phenomenon and drought-risk is not as clearly defined and understood as that from other natural hazards, such as floods or tropical cyclones. For this reason, although some regional and country-level data can be found, accurate global data on crop losses from agricultural drought are not available (UNISDR 2011b; UNISDR 2014). In the period 2008–2011 the direct and indirect losses from drought in Kenya were estimated at approximately US$12.1 billion across the entire economy (including agriculture), accounting for a reduction in GDP of 2.8 percent per year in that period (Cabot Venton et al. 2012).

Countries with small economies and trade limitations are very vulnerable to disaster loss, including those triggered by drought, and the impacts may have a significant lasting effect on the overall economic growth of a country (UNISDR 2009b). Findings from the 2009 and 2011 *Global Assessment Reports* of the United Nations Office for Disaster Risk Reduction (UNISDR) showed that drought risk is strongly dependent on rural vulnerability and on poverty, and that “rural poverty is both a cause and a consequence of drought risk” (UNISDR 2011a, 62; UNISDR 2009a). Addressing drought and other hazards by tackling the related vulnerability factors (that is, a disaster risk reduction approach) is therefore paramount if we are serious about poverty eradication, especially considering the expected growing threat from climate change during this century.

In fact, despite the uncertainty in climate models’ projections, climate scientists overwhelmingly agree that as climate change advances and higher temperatures set in, the frequency and severity of extreme weather events is likely to increase (Schiermeier 2012); analysis suggests that some regions of the world may see an intensification of droughts (IPCC 2012b) and will experience higher risk of crop losses (Li et al. 2009a). Yet it is not necessary for an event to be extreme in intensity and duration for the outcome to be disaster. Meteorological droughts are not a hazard per se, until they become hydrological or agricultural droughts; this transition depends on many factors including topography and soil characteristics, changes in water demand, and soil and water management practices (UNISDR 2011b). In turn, potentially hazardous droughts may have different impact magnitude depending on the vulnerability of the communities and of the economic system[1] exposed to the hazard.

Despite the threat, the UNISDR laments that “the political and economic reasons to invest in reducing drought risk are still weakly articulated” (UNISDR 2011b, 57). Aside from Australia and India, few countries have worked on national policies for drought risk management; hence institutions and governance framework to address this issue are often weak (UNISDR 2011b).

This report focuses on the relation between drought and food security in East Africa and in the Indo-Gangetic Plain (IGP) of South Asia. For the purposes of this study East Africa includes Sudan, Ethiopia, Eritrea, Somalia, Djibouti, Kenya, and Uganda. At times, to clarify concepts and ideas, examples may be used from other countries across SSA. For South Asia, the focus of the discussion will be on the western IGP, especially the Indian states at the border of India and Pakistan. The report has two goals: (1) to examine the factors behind the vulnerability of agriculture to droughts in these regions,

[1] The occurrence of a disaster is always preceded by the existence of specific physical and social conditions that are referred to as disaster risk. (IPCC 2012a)

including socioeconomic conditions, which the literature shows as a major driver for the rise in economic damages due to natural disasters (Barthel and Neumayer 2012); and (2) to identify the available options for drought risk reduction in the agriculture sector.

According to the United Nations Office for Disaster Risk Reduction, disaster risk reduction is about "analyzing and managing the causal factor of disasters, including through reduced exposure to hazards, lessened vulnerability of the people and property, wise management of land and environment and improved preparedness for adverse events" (UNISDR 2012, 8).

This report will focus mainly on different strategies to increase resilience[2] (that is, to reduce vulnerability) of the population in the two regions under study and will consider which drought-adaptation options are likely to be most successful. In doing so, we will explore technological solutions, through changes in agricultural practices, as well as policy interventions and socioeconomic instruments, including safety nets such as weather-index insurance. Reduction of exposure and improved preparedness will be mentioned only in passing.

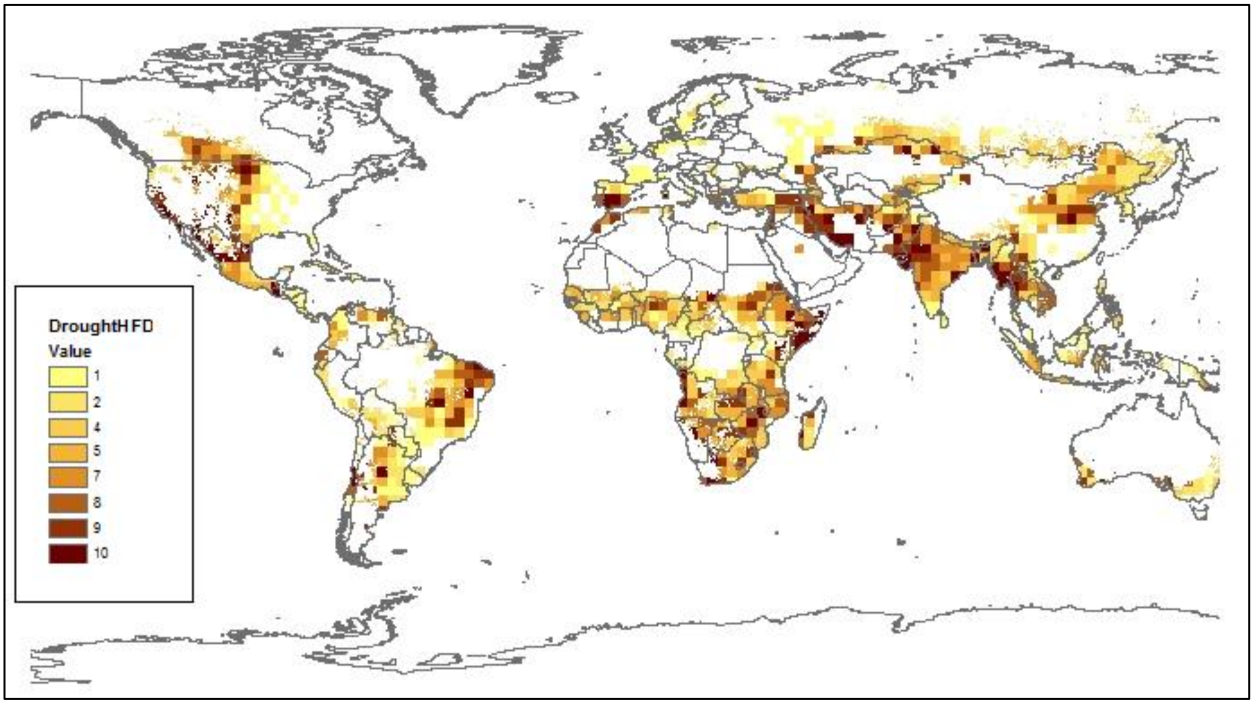
[2] "Resilience is the ability of an individual, a household, a community, a country or a region to withstand, to adapt, and to quickly recover from stresses and shocks." (European Commission 2012, 5)

2. VULNERABILITY

Vulnerability to Drought in Eastern Africa

Historical data indicate that eastern Africa is one of the regions of the world most hit by drought (Figure 2.1) (Hyman et al. 2008; Dilley et al. 2005). The EM-DAT international disasters database shows that the occurrence of drought events has been steadily increasing in eastern Africa during the past 50 years (CRED 2012) (Figure 2.2), and the Aqueduct Water Risk Atlas shows areas of high drought severity in parts of Ethiopia, Somalia, and Kenya and especially across Sudan (Figure 2.3).

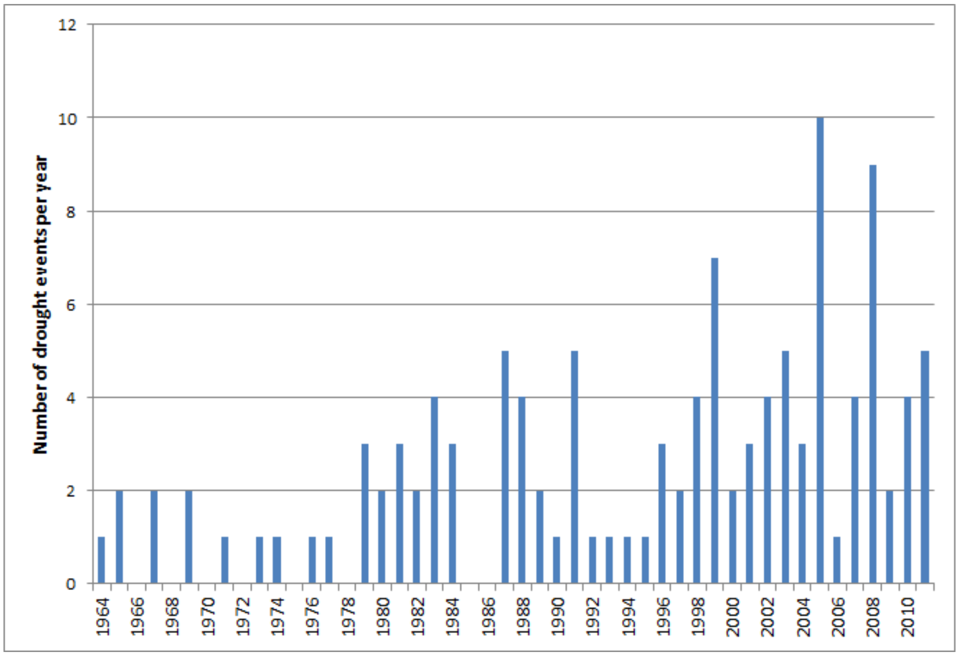
Figure 2.1 Global drought hazard frequency and distribution



Source: CIESIN (2005).

Note: Global drought hazard frequency and distribution is a 2.5 by 2.5 minute grid based upon the International Research Institute for Climate Prediction's (IRI) weighted anomaly of standardized precipitation (WASP). Utilizing average monthly precipitation data from 1980 through 2000 at a resolution of 2.5 degrees, WASP assesses the precipitation deficit or surplus over a three-month temporal window that is weighted by the magnitude of the seasonal cyclic variation in precipitation. Higher grid cell values denote higher frequencies of drought occurrence.

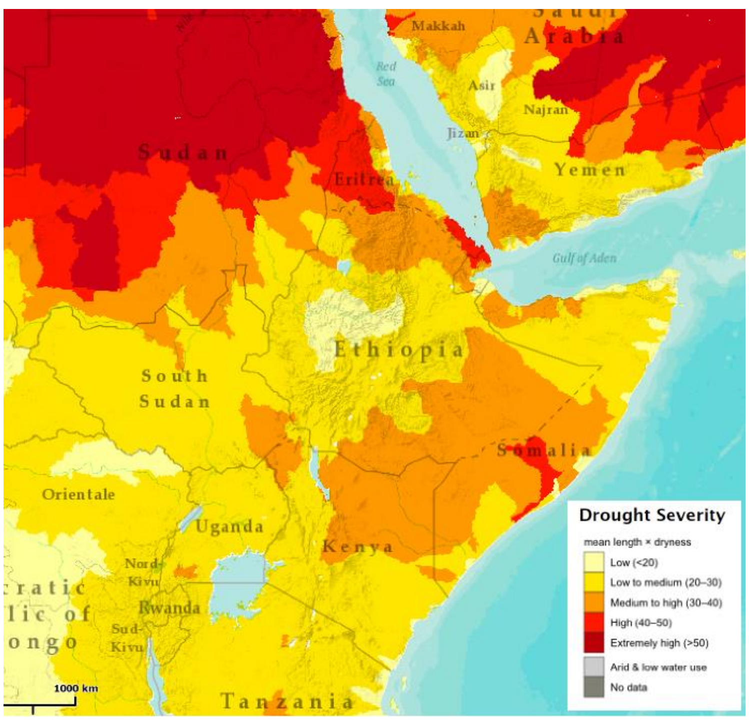
Figure 2.2 Number of drought events per year in eastern Africa, 1964–2011



Source: CRED (2012)

Note: Eastern Africa includes Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Somalia, Tanzania, Uganda, Zambia, and Zimbabwe.

Figure 2.3 Drought severity areas in eastern Africa



Source: World Resources Institute (2013)

Note: Drought severity measures the average length of droughts times the dryness of the droughts from 1901 to 2008. Calculation: Drought severity is the mean of the length times the dryness of all droughts occurring in an area. *Drought* is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in months, and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. Drought data are resampled from original raster form into hydrological catchments (Gassert et al. 2013).

Climate projections from the Intergovernmental Panel on Climate Change (IPCC) have pointed to a likely increase in annual mean rainfall in East Africa toward the midcentury (Christensen et al. 2007). A 2011 study has challenged these model results and predicted a higher likelihood of increasing frequency of droughts, particularly during the months of the long rains (*belgs*) between March and June (Williams and Funk 2011). In the recent past, observations on the ground are also showing decline in spring rainfall (Funk 2011), and other studies point to a long-term decline in rainfall and an increase in temperatures across some parts of Ethiopia, Kenya, Sudan, and Uganda (Funk et al. 2012a, 2012b, 2010).

Droughts (as well as other disasters) cause large human and economic losses across the whole of East Africa. At the end of the last decade, a combination of poor rainfall and rising food prices has increased the vulnerability of the population to the effects of droughts (Funk 2011); and in 2011, the Horn of Africa faced the worst drought in 60 years, with a total of more than 13 million people requiring assistance (Headey and Kennedy 2012).

The high vulnerability of population and institutions to drought-related shocks originates from a long history of exposure to natural hazards combined with several other factors: population growth, increased pressure on resources leading to land fragmentation, soil degradation and overexploitation of water resources, insecure access to land and water resources, conflict, and poor coping and adapting capacity (European Commission 2012; UNISDR 2012; Headey and Kennedy 2012). Decreased agricultural productivity resulting from drought-induced crop failure affects a population already living on few assets and low income. The new impacts further erode people's assets, thereby increasing vulnerability to additional shocks.

Vulnerability is compounded by the rise in frequency and intensity of drought events (Nicholson 2014; Omondi et al. 2014) and by the changing geographical patterns of these events (UNISDR 2012). A shift in the geographical location of precipitation is with greater regularity exposing populations that lack the experience and the knowledge to deal with droughts and other such events (UNISDR 2012). The increasing frequency of drought prevents people from fully rebuilding their livelihoods before the next event occurs. Therefore, the population risks being locked into a vicious never-ending cycle of poverty (a *poverty trap*) if the root causes of vulnerability are not addressed.

Country Case: Ethiopia

In Ethiopia, vulnerability to drought is caused principally by land degradation due to poor land management and high population density; it is estimated that 50 percent of all rural land in Ethiopia's highlands is degraded (Nedessa and Wickrema 2010). Several other factors compound the vulnerability, including Ethiopia's geography and topography, its dependence on rainfed agriculture, underdevelopment and poor management of water resources, low economic development, poverty, and weak institutions (GFDRR 2011).

The agriculture sector accounts for almost 48 percent of Ethiopia's GDP, in comparison to a 30 percent average in the whole Horn of Africa.[3] Most agricultural output comes from subsistence and smallholder farmers, and more than 85 percent of the population is employed and supports itself through agriculture (World Bank 2005). Production, represented mainly by cereals for direct consumption (wheat, maize, teff, and sorghum), is almost entirely rainfed, exposing the sector to high volatility and increasing the vulnerability of poor households, who lack opportunities to diversify their sources of livelihood. Droughts are recurrent in Ethiopia, and harvest failure as a consequence of drought events represents by far the major climate-related risk for rural households (World Bank 2006; GFDRR 2011; Hellmuth et al. 2007).

[3] World Bank data, WDI, accessed June 2012.

Decreases in farm production by up to 90 percent have been recorded in drought years; risk of crop failure due to weather shocks prevents farmers from investing in inputs (that is, water and fertilizers) and in improved agricultural technologies and practices, therefore thwarting average yields. The generally poor property rights prevent farmers from having secure assets to offer as collateral and decrease their chances to obtain credit (for example, bank loans) for production inputs. As a result, agriculture becomes a high-risk endeavor, and farmers remain locked in a low-returns production system. Because droughts also hurt livestock, a major source of wealth in the region, depletion of all major productive assets and limited access to credit increase the likelihood for rural households to fall into poverty traps and hamper their long-term growth opportunities (World Bank 2006).

The impacts of drought in Ethiopia are both short and long term. When the short rains fail, the food security of subsistence farmers is affected through direct impact on food crops and on livestock. Climate shocks, in combination with weak markets and poor infrastructure, further affect the poor by making prices of staple foods volatile, often resulting in price increases that imperil those households that spend most of their income on food. Public health threats have also been associated with drought. In the past, outbreaks of meningitis have hit the Ethiopian population during drought periods, and malaria has been a problem at the start of the first rains after dry periods (Lautze et al. 2003). Furthermore, measles has frequently hit children of refugees fleeing drought-stricken areas (Loewenberg 2011).

Country Case: Kenya

In Kenya drought is a common occurrence, and it usually hits the arid lands, which have higher poverty rates and lowest population density (World Bank 2011). The severity of the impact differs based on which areas are affected. The 2011 drought, differently from that in 2009, was limited to arid and semiarid areas— and usually the economic downturn is avoided as long as the drought does not hit the Rift Valley, Kenya’s bread basket (World Bank 2011).

Drought and food crisis affect the country through a combination of direct and indirect impacts. The main direct impact of drought is on the lives of the people who live in drought-stricken areas, particularly due to increased livestock mortality. Livestock represents the main asset and wealth for households living in arid areas and contributes 5 percent of total GDP. Impacts on pastoralists are particularly dire if we consider that in arid areas livestock mortality has been recorded as high as 48 percent even in non-drought years (World Bank 2011); during the 2011 drought, mortality was 10–15 percent above normal (about 5 percent of all Kenya livestock population). The other direct impact is on maize production. Kenya is a net importer of food even in periods of non-drought, and maize is the staple food in Kenya.

Indirect impacts occur through changes in food prices. Droughts normally drive up prices across the country and affect the majority of the poor, as they are net buyers of maize. The net producers may be able to benefit from higher prices induced by the drought, if they are not located in the directly stricken areas. For instance, in 2011 the net producers located in the Rift Valley were not hit by the drought and could benefit from selling at higher prices for the drought that hit northeastern and eastern Kenya (World Bank 2011).

Vulnerability to Drought in the Indo-Gangetic Plain

India has one of the highest average annual rainfall (more than 1,000 mm or about 4,000 km^3), but most of the precipitation occurs over the eastern part of the continent, and it is released in a relatively short time[4] through torrential downpours, which make both water harvesting and aquifer recharge more difficult (Shah 2009a). Because seasonal and geographical variation is large, some parts of the country suffer from recurrent droughts (Table 2.1). In Rajasthan, variability can be as much as a 40–50 percent deviation from the long-period average rainfall (India, Department of Agriculture and Cooperation 2009).

Table 2.1 Probability of occurrence of drought across meteorological subdivisions of India

Meteorological subdivision	Frequency of deficient rainfall (75% of normal or less)
West Rajasthan	Once in 2 years
Tamil Nadu, Jammu, Kashmir, Telengana	Once in 2.5 years
Gujarat, East Rajasthan, West Uttar Pradesh	Once in 3 years
South Interior, Karnataka, Eastern Uttar Pradesh, Vidarbha	Once in 4 years
West Bengal, Madhya Pradesh, Konkan, Bihar and Orissa	Once in 5 years
Assam	Very rare—once in 15 years

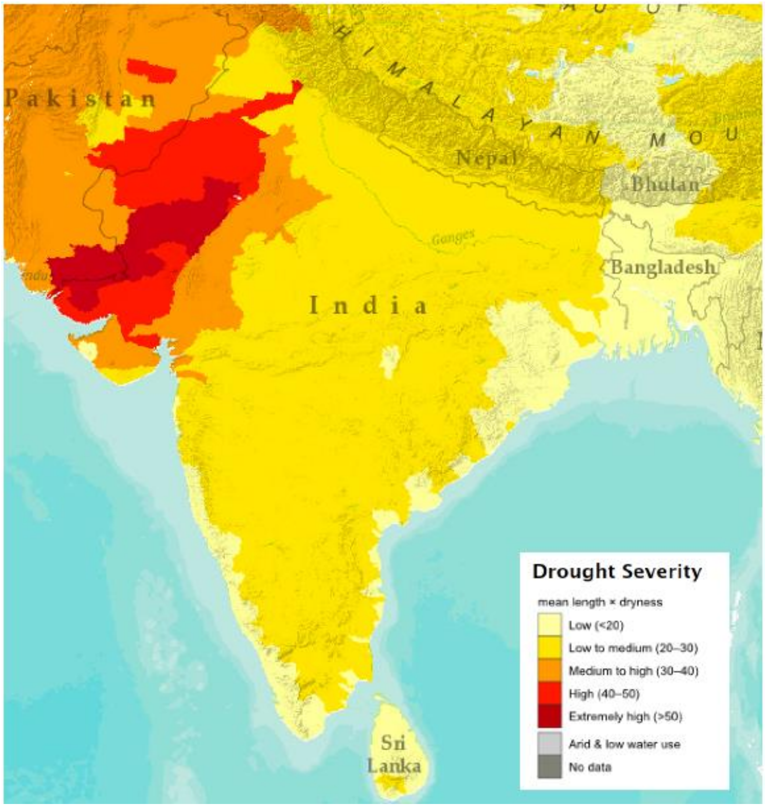
Source: Reproduced from National Rainfed Area Authority (2009).

The summer monsoon brings most of the rain to India, and due to its pattern the northwest of the Indo-Gangetic Plain (IGP) gets only about a month of rain per year.[5] The areas of northwest India are considered “low rainfall areas” by the definition of the India Meteorological Department (IMD), as they receive less than 750 mm of rain per year. In recent years, the frequent failure of the monsoon has aggravated drought conditions in these areas (India, Department of Agriculture and Cooperation 2009).

From an agroclimatic standpoint Rajasthan, Gujarat, and parts of Haryana, as well as parts of Pakistan at the border with India, are defined as arid zones and are drought hotspots (Figure 2.4). They experience severe droughts and receive an average annual rainfall between only 100 and 400 mm (India, Department of Agriculture and Cooperation 2009[6]).

[4] Shah (2009) estimates about 100 hours.
[5] Page 15 (India, Department of Agriculture and Cooperation 2009).
[6] Page 22; the arid zones are 19.6 percent of all India drought-prone areas.

Figure 2.4 Drought severity areas in South Asia



Source: World Resources Institute (2013).
Note: Drought severity measures the average length of droughts times the dryness of the droughts from 1901 to 2008. Calculation: *Drought severity* is the mean of the lengths times the dryness of all droughts occurring in an area. *Drought* is defined as a contiguous period when soil moisture remains below the 20th percentile. Length is measured in months, and dryness is the average number of percentage points by which soil moisture drops below the 20th percentile. Drought data are resampled from original raster form into hydrological catchments (Gassert et al. 2013).

In these areas, farmers cultivate mainly wheat, barley, pulses, millet, and sorghum, thus already adopting crops that are suitable to a drier climate. Other "common adaptations" are the use of agroforestry and cultivation of fruit trees (personal communication, Dr. Bharat R. Sharma, International Water Management Institute, New Delhi).

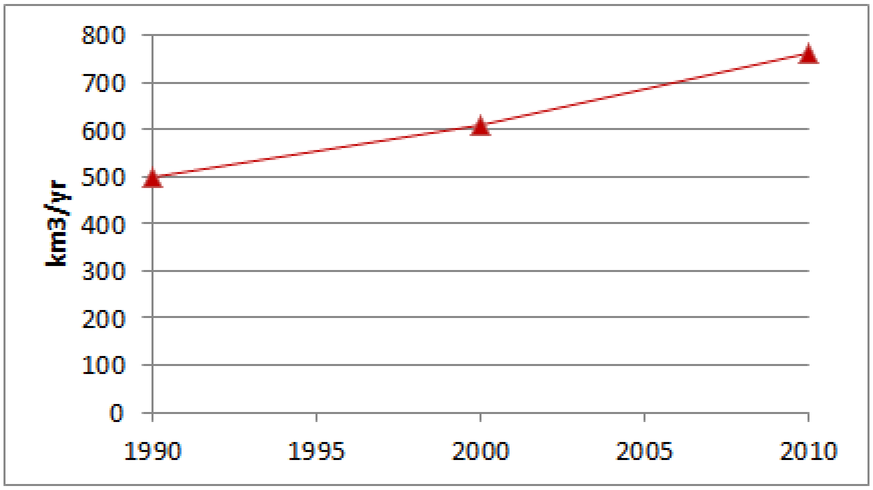
Analysis of a subset of expert opinion data from a CGIAR Generation Challenge Programme (GCP) survey[7] revealed that "drought and other types of water constraint are important but do not dominate constraint sets for major food crops in South Asian farming systems" (Li et al. 2011, 30).

The study explored the relative impact of drought and water-related constraints on the production of four major food crops (wheat, rice, sorghum, and chickpea) across five farming systems in South Asia. The analysis of expert opinion shows that drought and other types of water constraint are important in those farming systems that rely predominantly on rainfed dryland cropping. However, in the two farming systems characteristic of the Indo-Gangetic Plain, the rice–wheat system and the rainfed-mixed system, drought is responsible respectively for about 5 percent and about 10 percent of average yield losses, respectively. All water constrains, including drought, were reported to contribute to between 20 and 30 percent of all yield losses.

[7] Illustrated in Waddington et al. (2010).

Results of the survey show that soil fertility loss, negative impact of weeds on production, and poor use of fertilizers were often reported as having the largest impact on yield losses (Li et al. 2011). However, damages from drought and lower water availability should not be downplayed in the face of projected climatic changes and because of the increasing pressure on water resources. Agricultural droughts are already becoming a recurring phenomenon in India due to a nearly 50 percent increase in total water withdrawals in the last 20 years (Figure 2.5), and climate change may induce a significant increase in the percentage of areas affected by meteorological droughts across South Asia (Li et al. 2009b).

Figure 2.5 Total water withdrawals in India, 1990 to 2010



Source: FAO (2013).
Note: km3/yr = cubic kilometer per year

3. SOLUTIONS FOR DROUGHT RISK REDUCTION

For centuries, generations of farmers across the semidry and dry areas of the world have been developing mechanisms to cultivate crops and raise animals in these harsh environments. According to Cooper et al. (2008), the drought-coping strategies developed by farmers over generations in the arid and semiarid areas of SSA are mostly “risk spreading” measures; they can mitigate the negative effects of deficit rainfall but may not necessarily allow the farmers to address issues of soil fertility and significantly improve productivity during average or good seasons (Table 3.1). However, it is important to recognize that a very wide variety of strategies have been and still are being adopted between regions, villages, and even from household to household (Cooper et al. 2008).

Table 3.1 Examples of autonomous coping strategies from Africa south of the Sahara

Scale	Time		
	Before the season	**During the season**	**After the season**
Plant level	Selection of DT or HT varieties	Earlier maturing varieties	
Plot level	Changes in planting dates Changes in crops and adapting crops to land types Low-density planting Intercropping Delayed fertilizer use	Increasing or decreasing plant density	Grazing on failed plots
Farm	Diversified cropping	Shifting crops	
Household/village	Social & off-farm employment		Asset sales to purchase cereals Migration to find employment

Source: Adapted from Cooper et al. (2008) and Kristjanson et al. (2012).
Note: DT = drought tolerant; HT = heat tolerant

In the arid and semiarid areas south Asia, water harvesting, mixed farming, and diversification have been key components of farmers’ coping mechanisms (Oweis and Hachum 2009; Singh et al. 2009). Irrigation has also traditionally been central to agriculture in the Indo-Gangetic Plain, with strategies across centuries ranging from diversion of monsoon floodwaters, to water harvesting and storage in reservoirs, to large canal systems, to the more recent small-scale dispersed irrigation systems (Shah 2009a).

In both regions, different techniques and strategies have come and gone. Many water-harvesting systems have fallen in disuse (Oweis and Hachum 2009). The reasons why farmers may abandon some apparently successful techniques[8] and what they establish instead are unclear (Lahmar et al. 2012). One can hypothesize that issues related to labor intensity, loss of traditional knowledge on how to best make use of some techniques, or both, may represent part of the answer; however, this is a complex question that is better addressed in a dedicated study, and it is outside of the scope of the present report.

This section will discuss how to reduce vulnerability and increase resilience to drought in East Africa and the IGP by examining old and newer solutions relevant to the agriculture sector. The solutions are organized around some of the major dimensions of food security:

1. Availability of food
    - This includes both amount and availability of food, based on local production, cross-border trade, and availability of reserves.

[8] For instance, the Zai planting technique in West Africa, or traditional water-harvesting systems in parts of the Indo-Gangetic Plain.

2. Access to food
    - This refers to the ability of households to obtain food. This depends mainly on prices and markets, and on employment opportunities.
3. Utilization of food
    - This is about the physiological/biological ability of people to derive full sustenance from the food available. It relates to issues of public health and exposure to vector-borne diseases. Education and basic sanitation and health services are relevant factors.
4. Financial vulnerability
    - This relates to the loss of assets and productive power, and how to break the cycle triggered by these losses.

This report focuses on strategies and options to increase resilience of farmers to drought, assuming exposure to hazardous weather climatic conditions; however, disaster risk reduction includes measures to reduce exposure to the hazard, implicitly accepting that "certain areas are too fragile for sustainable farming or herding" (Molden 2007, 572). Migration is one of the options to reduce exposure. As drought and climate variability increase, the option of retreat (that is, migration) will increasingly be an appealing choice for communities now living in the most hard-hit arid areas of eastern Africa.

The 2009 World Bank *World Development Report* noted how, historically, development has been driven by people moving from poor, sometimes arid, regions to more populated and economically active areas (World Bank 2008). Institutions are necessary to facilitate this process in an organized way. For instance, human capacity (education and healthcare) must be strengthened in arid areas, so that the local populations are well equipped when and if they decide to move out (World Bank 2011). In addition, investments in infrastructure are needed (roads and telecommunications), together with programs to encourage economic activity. Infrastructure facilitates connection between those that migrate and the communities that stay behind, and therefore support for those who remain can be ensured. In Kenya, the development of the mobile phone network and the use of mobile phone to send money has facilitated the delivery of remittances as livelihood support between distant areas (World Bank 2011).

Adaptation Options: Availability of Food

Two general interventions to reduce the risk of drought losses on agricultural production and food availability are as follows:

1. Promote practices that can reduce the underlying vulnerability of the agricultural sector by improving overall agricultural production, and promote policies and measures that facilitate trade across borders
2. Promote the adoption of practices specifically tailored to help agricultural productivity in the event of rainfall deficit, or drought conditions

In drought-afflicted areas, the first step of any solution aiming at reducing the risk of losses and increasing the productivity of agriculture must be to control the erosion of the natural resources base.[9] The key to increasing productivity and food availability and building base resilience is the development of climate-smart and sustainable food production systems.

In some areas of East Africa, agricultural diversification, in combination with adoption of drought-tolerant varieties and planting of trees, has helped to both improve the resource base and increase production. Keys to success were community-based resource management and improving rights and access to resources, as well as long-term financing (Headey and Kennedy 2012).

[9] This increases the resilience of the resources to shocks.

Production and Food Availability—East Africa

Addressing the Underlying Fertility Issues: Soil Protection and Soil Moisture Conservation

African soils suffer from serious nutrient depletion (Bekunda, Sanginga, and Woomer 2010). A number of practices, adapted to specific local conditions, can help improve soil stability, soil structure, and fertility. The most common are improved fallow, mulching, management of crop residues (30 percent or more of the soil is covered with residues after harvest), improved compost and manure, use of inorganic fertilizers, integrated soil fertility management (Vanlauwe et al. 2010), low soil disturbance (reduced or no-till), conservation agriculture,[10] and water harvesting (Liniger et al. 2011; Molden 2007).

Some of the practices have the potential to rehabilitate soils by building up soil organic matter thanks to a combination of improved yields and increased production and reuse of crop residues. Crop residues benefit soil structure by protecting it from erosion and favor water infiltration and soil moisture maintenance; use of compost and manure provides mainly a source of nutrients and carbon (Liniger et al. 2011). All of the options described above promote soil quality and fertility and help soil-water retention, thereby increasing the resilience of soil to drought, while creating the conditions for increased productivity (Molden 2007; Liniger et al. 2011).

Research shows that adoption of practices that improve soil fertility and maintain soil moisture, along with adoption of improved drought- and heat-resistant varieties, can significantly improve agriculture productivity in drought-affected areas and protect farmers from production losses (Thornton et al. 2009; Schlenker and Lobell 2010). In addition, given the relevance of pastoralism in some arid areas of East Africa, managing livestock can prevent or reduce land degradation in the effort of increasing resilience to droughts. Destocking, that is, reducing the number of livestock to ease pressure on vegetation and soil during times of drought, is sometimes advocated to protect the natural resources base (Headey and Kennedy 2012); however, this requires cooperation and government intervention at both local and national levels to establish a market where livestock can be traded (UNISDR 2012; Headey and Kennedy 2012).

Autonomous or planned adaptation to drought has been studied and implemented across SSA (Box 3.1). Evidence from a survey conducted in East Africa in 2010–2011 suggests that many households have been adapting to the vast economic, demographic, and ecological changes that took place in the first decade of the new century, but data show that the measures taken by the farmers have been incremental and “marginal rather than transformational” (Kristjanson et al. 2012). Diversification was the most frequent change made by households to cope with the changing weather; this included varietal changes, modification in planting season—land preparation, planting times, and harvest—increased intercropping, more rotations, and use of better seeds and varieties, including drought-tolerant varieties (Kristjanson et al. 2012).

[10] *Conservation agriculture* refers to the use of residues and crop rotations, in combination with reduced or no-till. The website http://conservationagriculture.mannlib.cornell.edu/ contains up-to-date information, definitions, and data on conservation agriculture. Accessed January 2013.

Box 3.1 Tackling drought: Examples from southern Africa

Similar to conditions in East Africa, drought and declining soil fertility due to soil erosion and unsuitable cultivation practices are reported as the main challenges to farming systems in the South African countries of Swaziland, Botswana, and Malawi. In these countries, autonomous and planned (policy-guided) agricultural practices have been developed to counteract low agricultural productivity, to adapt to climate change, and to reduce risk of losses from drought and desertification.

In Swaziland, following observed delays in the rainy season, farmers diversified planting times across fields to limit the risk of crop loss. Use of fallow, crop rotation, and intercropping of maize with legumes (primarily cowpea) also increase soil fertility. Similarly, in response to changing rainfall and temperature patterns, farmers in Malawi are shifting their growing season and choosing different crops.

The progress report of the Swaziland National Action Programme (NAP) against desertification cites educational activities in support of conservation agriculture; increased water supply; and the introduction of high-yielding drought-, heat-, and disease-tolerant maize as critical measures to adapt to drought. Promotion of sorghum and cassava in the most drought-prone regions of the country is also highly encouraged. The report also suggests that deforestation and overgrazing (both drivers of land degradation) should be tackled, and that more finances should be made available to increase the use of fertilizers and hybrid seeds.

In Botswana, where livestock farming is the main agricultural activity, autonomous local measures to reduce land degradation and vulnerability to drought include shifting grazing. The strategy for rangeland rehabilitation includes use of wind-breaks to reduce wind erosion, and use of broken bushes on the ground to protect the recovering soil and grass from grazing. The Botswana NAP also promotes interbasins water transfers, water conservation measures, and improvements in water use efficiency as necessary planned measures against drought.

Source: Stringer et al. (2009).

Although on-farm diversification is thought to contribute to improving soil health and resilience to drought, the largest benefits can be accrued only through a full-landscape approach.[11] For instance, water cycling can be improved only if large areas of farmed and non-farmed land are managed together: Cultivated land should be organized in a mosaic of different crops and trees to protect the soil, to promote water infiltration, and to provide biomass for soil carbon rebuilding; and at the same time non-farmed land in and around farmland should be actively managed by protecting hillsides or river banks from erosion (Molden 2007).

In the 1970s and 1980s, recognizing the negative impact of soil erosion on the resilience of agriculture to climate shocks and following the massive famines of the 1970s, the Ethiopian government initiated a campaign to promote soil and water conservation (SWC) measures both in cultivated fields and on government lands (for example, hillsides of the highlands) (Tefera and Sterk 2010; Bewket 2007). The campaign failed to induce a long-term change in the adoption of agricultural practices, and farmers reverted to their usual practices as soon as the program ended (Bewket 2007). Although the reasons behind the failure are multiple and site specific, the major flaw of the program was a top-down approach with little concern for farmers' needs and priorities. Limited access to information, diffidence of farmers toward the actual productivity of the measures, and weak land tenure also affected the outcome (Bewket 2007).

The program promoted the use of water-harvesting structures that were labor demanding in construction and maintenance, and difficult to build without external assistance. Adoption of SWC practices was particularly low in those areas where farmers did not have secure property rights on the land. The combination of lack of tenure and high labor requirements represents a level of risk too high for the farmers to bear, especially so because benefits from the SWC measures start to accrue only after a few years (that is, a delay in returns to investments) (Bewket 2007; Shively 1997; Teklewold and Kohlin 2011).

[11] See following discussion on Ethiopia's MERET project.

Despite evidence of positive returns from the adoption of SWC practices, and the proven effects on yields,[12] the adoption of beneficial soil and water management practices is still low (Teklewold and Kohlin 2011). Extensive research in this field tells us that the main causes are the initial investment to establish the new practices; the lack of public investments in other areas, especially in building infrastructure and improving farmers' access to markets (Enfors and Gordon 2008); labor shortage and labor costs to establish and maintain SWC technologies; insecurity of land tenure; and the challenge of designing practices that fit with famers' requirements (Bewket 2007; Tefera and Sterk 2010).

In the last decade the government of Ethiopia, in collaboration with the World Food Programme, tackled these constraints through a project that fostered active local participation while also recognizing land tenure and ensuring sustainable financing and technical support and education. The project, called Managing Environmental Resources to Enable Transitions to more sustainable livelihoods (MERET), is an example of integrated landscape management, which succeeded in building assets and resilience to drought by reconciling SWC with farmers' priorities (Box 3.2). It was built on the realization by Ethiopia's Ministry of Agriculture that the top-down approach had failed and that communities had to gain control over decisions that affect their livelihoods. Moreover, the Ministry of Agriculture as well as foreign donors active in the country realized that the landscape rehabilitation work had to rely on wide-scale capacity building, because the needs and requirements of the communities were going to be achieved only through technically sound SWC activities targeted to diverse environments and watershed characteristics (Nedessa and Wickrema 2010).

Farmers experience risk from a range of factors other than tenure status, including imperfect credit and insurance markets, low level of infrastructure, and poor access to both input and output markets (Teklewold and Kohlin 2011; Enfors and Gordon 2008). Better access to information, education, and extension services contributes to reducing risk (Teklewold and Kohlin 2011). Along with people's natural preferences, these factors determine the willingness of farmers to invest in agricultural development, including those practices that help reduce the impacts of drought.

[12] This is often calculated as several times greater than what the farmers currently achieve.

Box 3.2 MERET, an integrated landscape management approach to disaster risk reduction

Managing Environmental Resources to Enable Transitions to more sustainable livelihoods (MERET) is a project coordinated by the Ethiopian government with the support of the World Food Programme (WFP) through which chronically food-insecure communities living in drought-prone and environmentally degraded agroecological areas engage in environmental rehabilitation and income-generating activities.

The program now covers more than 450 watersheds across five regions (Amhara; Oromiya; SNNP, Tigray; and Somali) and the Dire Dawa Administration. Since its launch in 2003, the program has succeeded in rehabilitating more than 400,000 hectares of degraded land (including farmland and forests) and has achieved a 20 percent reduction in poverty in its project areas. The key characteristics of the program are community empowerment and the facilitation of technology adoption and innovation.

The project is owned and implemented by the government of Ethiopia and by local communities, and supported by the WFP through food assistance and technical advice. At its core it is a participatory integrated watershed management operation based on the critical recognition that land degradation is an ecological as well as a socioeconomic issue. In practice, rehabilitation of degraded land through soil and water conservation practices and reforestation improves soil fertility and allows the development of complementary income-generating and income-diversifying activities, such as planting of fruit trees, horticulture, and beekeeping. These income-generating activities are designed by the community, especially women, thanks to their inclusion in planning, management, and prioritization of the work.

As part of the environmental and sustainable land management program, the main restoration components have included soil and water conservation practices like composting and manuring; water harvesting systems such as sediment storage dams and check dams; eyebrow basins and percolation pits adapted to steep terrains and rain bursts; and planting of trees, shrubs, herbaceous plants, and legumes to increase soil fertility. The gradual introduction of these components showed the farmers the positive effects of these methods and helped increase their popularity and adoption. A focus on technical innovation was possible thanks to the strong partnership between WFP and the extension system of the Natural Resources Department, the implementing agency. Extension agents, often soil and water conservation engineers, work in close collaboration with the community to help select and plan the work activities, which need to combine environmental, social, and economic needs. WFP provides food for part of the year in return for work on the landscape, provides technical advice and capacity development activities, and provides monitoring and supervision support, but the actual activities are chosen by the community.

The project has demonstrated how community organization supported by technical information and education can transform a whole landscape on the basis of good scientific hydrologic principles, can respond to the needs and priorities of the community, and can build resilience to economic (for example, price change) as well as weather-related shocks (for example, drought).

Sources: Nedessa and Wickrema (2010); Tongul and Hobson (2013); World Food Programme (2012).

Increasing Productivity in Drought Conditions: Role of Irrigation

Currently, agriculture in SSA is predominantly rainfed. Only about 4 percent of total cropland is equipped for irrigation, of which an estimated 75 percent is actually irrigated (Kadigi et al. 2012), and agricultural water withdrawals amount to just 1.3 percent of total renewable water resources (Svendsen, Ewing, and Msangi 2009). In eastern Africa, Djibouti is an exception, having the entirety of crop production under irrigated conditions. In the remaining countries the share of cultivated land under irrigation is less than 20 percent (Table 3.2)

Table 3.2 Share of cultivated area under irrigation in countries of eastern Africa

Country	Cultivated area equipped for irrigation (%)
Djibouti	101.2
Eritrea	5.49
Ethiopia	2.82
Kenya	1.78
Somalia	19.46
Sudan and South Sudan	10.97
Uganda	0.16

Source: FAO (2013).

Improved access to water for irrigation or supplemental irrigation can prolong the growing period, avoid false start,[13] and reduce the risk of impacts from dry spells, both for large-scale as well as smallholder farmers (Oweis and Hachum 2009; Araya and Stroosnijder 2011). Modern irrigation techniques can be effective in combating desertification and drought in arid areas (Salinas and Mendieta 2013).

Few studies have tried to assess the potential for irrigation expansion in SSA, and their results strongly depend on the methodology used. You et al. (2011) used a combination of biophysical and socioeconomic models to simulate the potential to expand irrigation in the African continent through large-scale (dam-based) and small-scale (appropriation of runoff) solutions. In their methodology the profitability of large-scale projects is very “sensitive to topography, distance between crops and dam, and costs for water conveyance, whereas smalls scale developments are sensitive to the availability of surface water run-off, on-farm investments costs, crop mix and market accessibility” (You et al. 2011, 775). According to this study the potential 50-year increase in irrigated area in SSA is 15.2 million hectares (ha) from large-scale projects, with an average 5.7 percent internal rate of return (IRR), and 6.7 million ha from small-scale interventions.[14] The eastern African countries (Ethiopia, Somalia, Eritrea, Djibouti, Kenya, Uganda, and Sudan) would benefit from a cumulative 3.8 million ha of increased irrigated land using large-scale infrastructure projects, and another 1.1 million ha from small-scale irrigated schemes based on appropriation of runoff[15] (Table 3.3). Moreover, all the eastern African countries show an IRR of 12 percent or higher for small-scale irrigation expansion, with a high of 64 percent for Somalia and 40 percent for Kenya (You et al. 2011). This is relevant, as a large survey of past irrigation projects in 50 countries worldwide estimated that projects with an IRR of less than 10 percent resulted in failure of the scheme (Inocencio et al. 2005).

[13] “Early onset of the rainy season leads to crop germination, since most farmers sow in dry soil. If a long dry spell follows, the seedlings die and often the crop must be re-sown” (Araya and Stroosnijder 2011, 425).

[14] When accounting for different investment costs, the total potential irrigated area from large-scale and small-scale projects for the whole of Africa would range between 6.7 million and 32 million hectares (You et al. 2011).

[15] *Runoff* is defined as water available for irrigation after evapotranspiration and groundwater recharge.

Table 3.3 Potential irrigation expansion through large-scale and small-scale interventions: First 20 countries, ranked for area expansion

Large-scale (dam-based) interventions			Small-scale interventions		
Top 20 countries	Increase in irrigated area (1,000 hectares)	IRR %	Top 20 countries	Increase in irrigated area (1,000 hectares)	Average IRR %
Nigeria	3,169	6.14	Nigeria	2,505	22
Benin	1,584	6.45	Uganda	620	32
Guinea	1,207	3.97	Morocco	309	11
Mozambique	1,033	5.35	Mali	302	60
Ethiopia	751	7.05	Tanzania	299	28
Tanzania	713	2.81	Cameroon	298	29
Zambia	660	4.41	Chad	277	27
Zimbabwe	580	8.17	Sudan	276	16
Senegal	546	9.64	Tunisia	195	21
Uganda	531	2.36	Mozambique	190	12
Cameroon	505	5.32	South Africa	189	14
Algeria	468	7.83	Ivory Coast	185	8
Ivory Coast	455	8.24	Malawi	162	10
Congo DRC	441	3.03	Ethiopia	156	12
South Africa	377	8.43	Congo DRC	138	12
Morocco	354	17.82	Niger	127	40
Sudan	352	-	Algeria	122	18
Kenya	288	7.04	Senegal	119	19
Burkina Faso	275	4.03	Guinea	117	7
Ghana	242	5.75	Benin	113	8

Source: You et al. (2011).
Notes: Countries in red type are part of eastern Africa for the purposes of this report; IRR = internal rate of return.

In a recent study, Xie et al. (2014) combined GIS analysis (Geographic Information System), biophysical and economic predictive modeling, and crop mix optimization techniques to calculate the potential for expanding smallholder irrigation across SSA through four distinct methods for capturing and diverting water. They found a larger potential for smallholder irrigated land expansion compared with that in the work of You et al (2011). Based on their methodology, use of motor pumps has the largest potential for increasing smallholder irrigated area across the region, under current climatic conditions and baseline assumptions on irrigation costs and crop prices. Treadle pumps, small reservoirs, and communal river diversion follow, in this order (Table 3.4). The cumulative potential across the four irrigation methods was found to be largest in Nigeria. However, Ethiopia and Uganda are also among the countries with the largest potential (Xie et al. 2014).

Table 3.4 Estimated potential expansion of smallholder irrigation in Africa south of the Sahara, current climate

Irrigation method	Smallholder irrigated area (thousand hectares)	Net revenue (US$, billion/year)
Motor pumps	29,662	22.1
Treadle pumps	24,351	19.3
Small reservoirs	22,176	20.2
Communal river diversion	20,439	13.7

Source: Xie et al. (2014).

Sensitivity analysis, based on different irrigation costs and crop prices, shows high levels of uncertainty for irrigation expansion potential across SSA. The potential expansion ranges between 18 million and 31 million ha for motor pumps, between 16 million and 25 million ha for treadle pumps, between 6 million and 26 million ha for communal river diversion and between 9 million and 22 million ha for small reservoirs. Additional research was conducted by Xie and colleagues considering the effects of climate change on potential irrigation expansion. Results related to a dry and a wet future climate are available at http://investmentvisualizer.agwater.org/.[16] For East Africa, a future dry climate does not appear to substantially affect the potential for expansion under the various technologies (Table 3.5). On average, across East Africa and across all technologies, a drier climate would decrease net revenues by 8 percent, whereas the potential area covered by irrigation would decrease by only about 1.3 percent, and the amount of rural population reached would be only about 2 percent lower compared with the effects of the technologies under the current climate.

Table 3.5 Potential expansion of smallholder irrigation in eastern Africa, current and dry climate

Climate	Technology	Smallholder irrigated area (thousand hectares)	Net revenue (US$ billion/year)	Rural population reached (thousand people)
current	Small reservoirs	4,277	6.8	73,828
current	Motor pumps	4,978	6.4	31,923
current	Treadle pumps	4,504	6.08	46,102
current	Communal river diversion	4,486	4.25	25,600
dry	Small reservoirs	4,438	6.54	75,693
dry	Motor pumps	4,464	5.49	28,087
dry	Treadle pumps	4,216	5.33	42,530
dry	Communal river diversion	4,898	4.28	27,659

Source: Agricultural Water Management Solutions (2013).

Some efforts have been made to introduce treadle pumps in areas with sufficient water resources. In general, African groundwater resources are still underused, although in some areas they are already overexploited (Kadigi et al. 2012). Treadle pumps are easy to use and carry around; they do not need electricity to function, and this made them popular among smallholders who are often stymied by poor access to credit. However, treadle pumps need a stable, reliable source of water to work; and in areas where water is not reliable, the pumps have not been successful. In these areas farmers have been relying instead on drip irrigation to increase water use efficiency. Drip can also be inexpensive, although it is often labor intensive (GDN and Babel Press 2013b).

Access to irrigation technology is challenging in many parts of SSA. Often the plots of land are too small to allow farmers to invest, and in many areas water is simply not available in large enough quantities. In these regions, without reliable rainfall or a reliable source of water for irrigation, people need to find other solutions: conserving moisture in the soil, and using new crop varieties that are more tolerant to water scarcity and drought (GDN and Babel Press 2013b)

Although studies are showing that the potential for profitable irrigation expansion is large, the challenges to actually achieve this potential are many. In Africa past irrigation projects based on surface water, either larger irrigation schemes or smaller river diversion projects, have failed due to a series of factors, beginning with a government-controlled, highly centralized and bureaucratic management

[16] "To investigate the impacts of climate change on the expansion potential of agricultural water management strategies, results were estimated under three climate scenarios. The baseline climate reflects actual 2000–2010 climate. Two alternative scenarios represent the "driest" and "wettest" scenarios among 12 future climate change scenarios for 2050 projected by general circulation models for each region. In sub-Saharan Africa, these models were the CSIRO-Mk3.0 model and the CNRM-CM3 model; while in South Asia, the CSIRO-Mk3.0 model and the MIROC 3.2 (medium resolution) model results represent the driest and wettest outcomes, respectively. The CSIRO and CNRM models were run under the SRES A2 emissions scenario, which is considered moderate. The MIROC model was run using the SRES A1B emissions scenario to reflect the wettest outcome for the region." Accessed in May 2013 from http://investmentvisualizer.agwater.org/.

rendered inefficient by high administrative costs and poorly trained managers. Dismal operational performance was caused by poor planning, including the low quality of feasibility studies, and by unrealistic estimates of costs and benefits. Furthermore, low implementation capacity caused delays, which led to decay of irrigation infrastructure before completion, higher costs, and poor returns (Kadigi et al. 2012).

To correct these failings, some reforms were encouraged in the 1980s and 1990s, with the intent of reducing government involvement and encouraging private-sector participation, shifting from large-scale to small-scale and simpler schemes, and transferring management of irrigation to the farmers. The involvement of farmers in maintaining and running the projects has led to the creation of water user associations (WUA) and other farmers' organizations devoted to the management of irrigation schemes (Kadigi et al. 2012). Research findings worldwide indicate that farmers' involvement at the planning and implementation phases of the irrigation projects can raise the likelihood of success, both technical and financial. However, the experience has been mixed so far, both in SSA and across the world (Kadigi et al. 2012).

Problems originate from high transaction costs and management issues, including poor leadership and low involvement of farmers. Where management has been successfully transferred to farmers, other well-known problems have surfaced to hinder irrigation development. Specifically, lack of formal land titles discourages the farmers from investing in costly maintenance and deprives them of collateral to offer in exchange for loans. Even when credit can be obtained, the cost of machineries and maintenance is often very high. Under these circumstances, lack of market opportunities becomes a critical issue, because for farmers to invest, they must have confidence that they can sell their products (Kadigi et al. 2012).

In general, success of irrigation investments is highly dependent on the quality of both input and output markets. In addition to irrigation development, complementary investments are needed to facilitate access to markets, through provision of infrastructure for transportation (roads) and storage, and to support access to inputs, especially fertilizers [17](You et al. 2011; Kadigi et al. 2012). Moreover, extension services are critical to inform about and provide access to new technology as well as to teach the farmers new skills on how to run irrigation schemes both technically and financially (Kadigi et al. 2012), but extension services in SSA still focus overwhelmingly on rainfed agriculture (GDN and Babel Press 2013b).

In Ethiopia, where 95 percent of agricultural production is still rainfed, poor extension services cause farmers to be ill-informed about modern irrigation techniques. Development of the whole irrigation sector is thwarted by lack of access to credit, as modern irrigation technology is not affordable for most farmers and they need support from the government or foreign donors. Often, when credit is available to buy the equipment, farmers do not have the skills and knowledge to run and maintain the equipment. In addition, no insurance is available to cover the costs if something goes wrong. As a result, farmers are reluctant to buy pumps.

Several irrigation projects have been launched and abandoned in the past, and many are in a state of disrepair (Kadigi et al. 2012). In 2001, the Ethiopian government launched the Dodicha irrigation pilot project in the south of Ethiopia to produce beans for the international market, and by 2012 the project was in shambles (including broken pipes and abandoned infrastructure). Farmers did not feel they had a stake in the project, the extension workers were not able to transfer the skills and knowledge to maintain and run the system, and the government had no capital to repair pumps and canals (GDN and Babel Press 2013b).

In 2010, the Ethiopian government launched the growth and transformation plan, with the goal of increasing the area under irrigation six fold over the next five years. This time, the preferred solution to remedy the lack of infrastructure, technology, and know-how has been to attract foreign direct investments. The result is that so far about 10 percent of all arable land is now owned by foreign investors (GDN and Babel Press 2013b).

[17] This includes chemical fertilizers, manure, and mulch.

Production and Food Availability—Indo-Gangetic Plain

The soil of vast areas of India are both thirsty and hungry, lacking water as well as sufficient nutrients due to a lack of fertilizer use (National Rainfed Area Authority 2009; Singh et al. 2009). About 50 percent of the geographic area of the state of Haryana is affected by severe land degradation due to erosion, alkalinity, salinity, and waterlogging (Planning Commission of India 2009). In response, several schemes have been launched by the local government and by other institutions to protect land and increase resilience to drought through construction of check dams, water-harvesting structures, gully control, and vegetation barriers (Planning Commission of India 2009).

Drought mitigation measures include medium- to long-term options, as well as interventions taken at the onset of the drought phenomenon, as part of contingency plans. In both circumstances, suggested interventions fall within a number of recurrent categories:

1. Practices to save water (increase in water use efficiency)
2. Selection of crops, cropping sequences, and agronomic practices for soil and water conservation
3. Livestock management (establishment of well stocked fodder-feed depots)
4. Availability of information—gathering and disseminating information on a real-time basis
5. Alternative employment schemes

The National Rainfed Area Authority of India has published a complete set of recommendations for long-term reduction of vulnerability to drought (Table 3.6). Among the various strategies, one of the first to be implemented has been a change in crop varieties. Rajasthan, Haryana, and Gujarat already have a number of early maturing crop varieties available, including chickpeas, moth bean, horse gram, guar, sorghum, and several species of millet. Foxtail millet is recommended in western Rajasthan for its good harvest under drought conditions, even at less than 400 mm of rain per year. In Gujarat small millets like *kodo* and *proso* are recommended under extreme drought and erratic monsoon conditions as they can produce a fast and abundant harvest for both fodder and grain (National Rainfed Area Authority 2009).

Table 3.6 Medium- and long-term strategies to reduce drought vulnerability in India

Securing and saving water	**Groundwater recharge mainly through in situ and ex situ water harvesting (contour bunding and so forth)**
	Switching to less-water-demanding crops
	Micro-irrigation: drip and sprinkler
	Periodic desilting and renovation of farm ponds and tanks
	Construction of additional *nadis* and *khadins* (traditional water-harvesting systems)
	Recycling of used water or wastewater after proper treatment*
Securing fodder for livestock	Introducing fodder trees, bushes, and grasses to rehabilitate wasted or abandoned lands
	Creation of permanent fodder feed and seed banks
Improved cropping and farming systems for soil and water conservation	Mixed cropping and intercropping
	Mixed farming and cropping systems
	Agroforestry
	Silvi and horti pasture
	Zero tillage
	Bed furrow irrigation
	Mulching
	Early maturation short duration crops

Source: National Rainfed Area Authority (2009).
Note: * Rajasthan has water at high fluoride and nitrate content, which can be purified with specific filters.

Protecting Soils and Soil Moisture

The government of India regularly publishes guidelines for drought relief and drought mitigation. The published guidelines provide recommendations for soil and water conservation at the ecoregion (Table 3.7) or state level so as to tailor drought management measures to the circumstances of different areas (that is, areas of recurring drought, or subhumid areas experiencing an anomaly) (India, National Disaster Management Authority 2010; India, National Rainfed Area Authority 2009; India, Department of Agriculture and Cooperation 2009).

Table 3.7 Soil and water conservation measures for different ecoregions

Rainfall (millimeters)	In situ soil and water conservation	Rainwater harvesting
Arid zones (<500)	Contour farming/cultivation Mulching Deep plowing Inter-row water conservation systems	Field ponds/tanks Revival of old traditional water harvesting systems (*khadins*)
Semiarid (500–1000)	Conservation furrows Contour farming Bunding Runoff strips Tied ridges Graded ridging Mulching Live edges	On-farm reservoirs Pond/tanks Wells Polyethylene lined tanks/ponds Revival of old abandoned traditional water-harvesting systems Groundwater recharge measures Recharge of old abandoned wells Check dams/gully plugs Water harvesting with spillways Micro-irrigation (sprinkler, drip)
Subhumid (>1000)	Field bunds Graded bunds Vegetative bunds Level/graded terraces Contour trenches Raised beds	Microcatchments Check dams Bench terrace Seepage pits Subsurface water collections Water harvesting with spillways Micro-irrigation (sprinkler, drip) Measures to reduce storage losses

Source: Adapted from National Rainfed Area Authority (2009), page 70.

Drought mitigation programs have existed for a long time in India, but their impact has been thwarted, mainly because of isolated implementation, fragmented across different sectors and departments.

To improve drought management and guide long-term strategies against drought, the government of India instituted the National Rainfed Area Authority (NRAA). This body has the task to assist state governments in the development and implementation of drought mitigation strategies. The mission of the NRAA is predominantly to manage and upgrade dryland and rainfed agriculture in order to adapt its practices to droughts (India, Department of Agriculture and Cooperation 2009).

Between the late 1990s and the early 21st century, the preexisting Desert Development Programme (DDP) was strengthened in Gujarat, Rajasthan, and Haryana to increase dune stabilization and establish shelterbelt plantations to protect soil from erosion. The measures achieved good results in terms of reduced soil erosion and increased land productivity (India, Department of Agriculture and Cooperation 2009). Strategies implemented in drought-prone areas included the following:

1. Shelterbelt plantation
2. Sand dune fixation
3. Afforestation
4. Artificial groundwater recharging
5. Repair and renovation of tanks and wells for water harvesting
6. In situ soil and moisture conservation

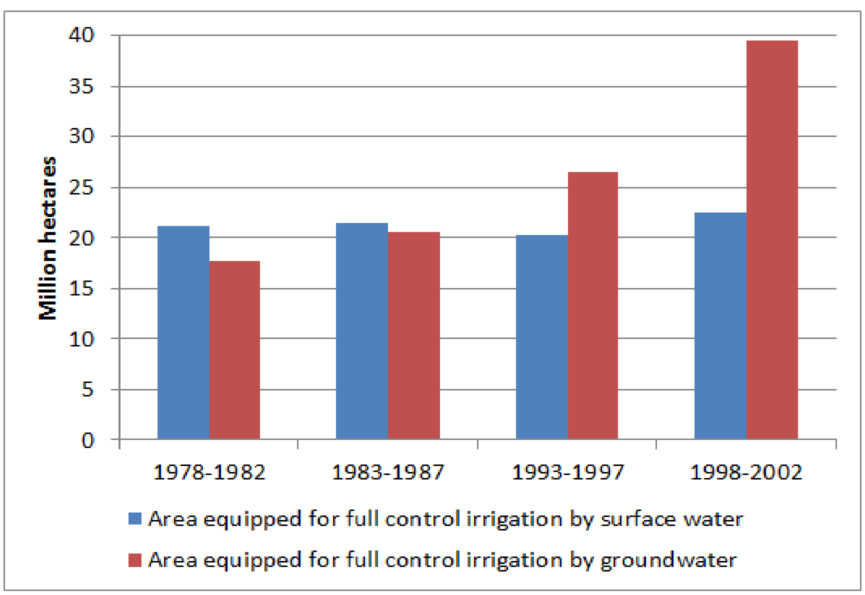
To further strengthen the drought mitigation approach, in 1994 some long-running programs like the Drought Prone Areas Programme (DPAP), the DDP, and the Integrated Wasteland Development Programme (IWDP) were reviewed and given common guidelines. In 2009 these three programs were united into a single Integrated Watershed Management Programme (IWMP).

Irrigation against Drought

Irrigation has always been an integral part of agriculture in the plains of South Asia (India, Pakistan, lower Nepal, Bangladesh, and Sri Lanka) (Shah 2009a), and about 40 percent of all crop area in South Asia (SA) is currently irrigated (Hasanain et al. 2012). However, South Asia and the IGP face periodic water shortages caused by a combination of large spatial and temporal rainfall variability, increasing pressure on water resources, and policy and management failures. The overuse and inefficient allocation of water resources in the IGP and across South Asia exacerbate shortages, threaten the ability to increase agricultural production, and thwart the efficacy of irrigation as a drought risk reduction strategy (Hasanain et al. 2012; GDN and Babel Press 2013a).

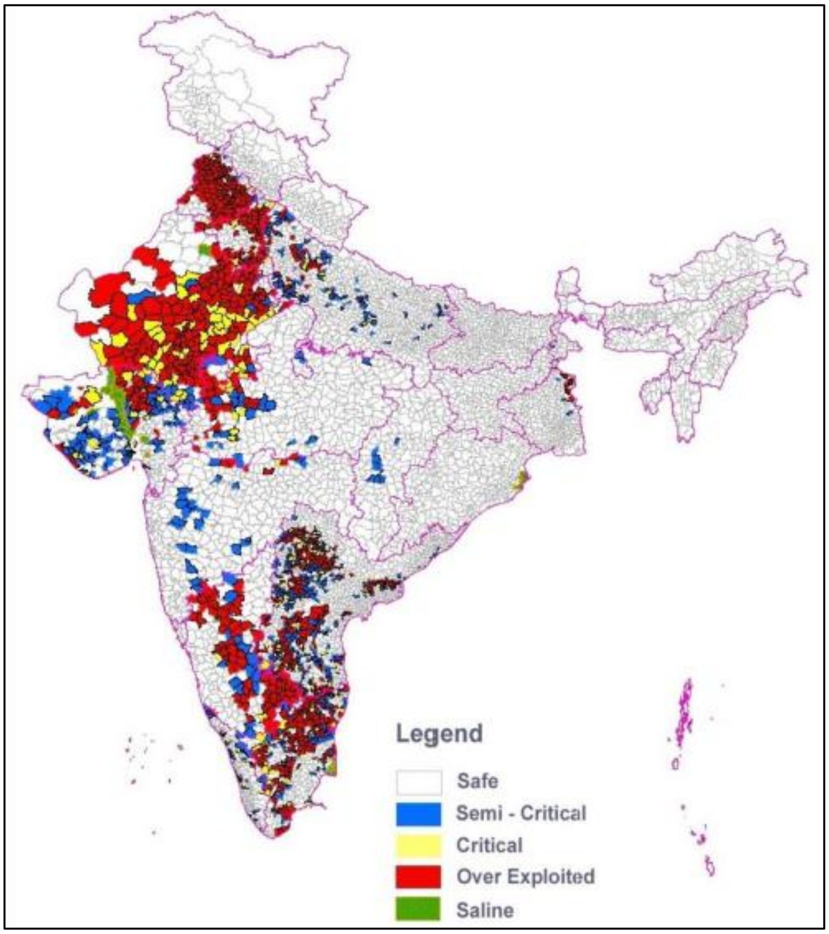
The exploitation of groundwater resources has been a driver for most of the irrigation development that took place in the Indo-Gangetic basin during the mid-1980s thanks to the advent of affordable tube wells and pumps (Molden 2007; Shah 2009b) (Figure 3.1). Because the Indian government subsidizes electrical power and pumps in the western IGP, and water laws entrust full groundwater use based on landownership, farmers enjoy full control over extraction, and pumping of groundwater is virtually unregulated, unmonitored, and untaxed (Hasanain et al. 2012; Planning Commission of India 2008). This translates into a complete lack of economic incentives toward efficient and careful management of groundwater resources, and it has led to widespread mismanagement of aquifers (Figure 3.2).

Figure 3.1 Evolution of area equipped for irrigation in India: By source



Source: FAO (2013).

Figure 3.2 Status of groundwater resources in India by assessment unit



Source: Planning Commission of India (2007).
Note: The assessment units in the map correspond to different administrative levels. Definitions can be found in Annexure 2.3 of the source document.

The Indian states of Haryana and Rajasthan in the western IGP are examples of regions where the availability of either surface or groundwater for irrigation is insufficient due to a combination of dry climate and bad resources management (Planning Commission of India 2006; Planning Commission of India 2009).

In the semiarid states of Haryana, Punjab, and Rajasthan, groundwater is overexploited, with the rate of abstraction exceeding the rate of recharge. Across India, “out of the 5,723 assessment units, 4,078 are safe (71 percent), 550 are semi critical (10 percent), 226 are critical (4 percent) and 839 are over exploited (15 percent)” (Planning Commission of India 2007). In six states (Gujarat, Haryana, Maharashtra, Punjab, Rajasthan, and Tamil Nadu), 762 assessment units out of a combined total of 1,413 were identified as semicritical, critical, or overexploited. This corresponds to 54 percent, compared with a national average of 29 percent (Planning Commission of India 2007).

Moreover, throughout the agriculture and water sector, surface irrigation projects have been mired by managerial and organizational problems that led to resource deterioration through faulty project design, shoddy maintenance of the distribution channels, and inefficient distribution and unequal allocation of resources (Planning Commission of India 2013; Hasanain et al. 2012). The last two decades have seen a recognition of the organizational nature of the problem and a move toward support of water user associations (WUAs) and farmers’ organizations for control of surface irrigation schemes (Table 3.8).

Table 3.8 State-wise number of WUAs and area covered

State	Number of WUAs formed	Area covered (thousand hectares)
Andhra Pradesh	10,790	4,800.00
Arunachal Pradesh	2	1.47
Assam	37	24.09
Bihar	37	105.80
Chhattisgarh	945	NA
Goa	42	5.00
Gujarat	576	96.68
Haryana	2,800	200.00
Himachal Pradesh	875	35.00
Jammu and Kashmir	1	1.00
Karnataka	2,279	1,052.41
Kerala	3,930	148.48
Madhya Pradesh	1,470	1,501.45
Maharashtra	1,299	444.00
Manipur	62	49.27
Meghalaya	99	NA
Negaland	25	NA
Orissa	11,020	907.00
Punjab	957	116.95
Rajasthan	506	219.65
Tamil Nadu	7725	474.28
Uttar Pradesh	24	10.55
West Bengal	10,000	37.00
TOTAL	55,501	10,230.08

Source: Extracted from Planning Commission of India (2008).
Note: WAU = water user associations.

As the population continues to grow, putting more pressure on water resources, and as climate change increases weather variability and modifies the storage and release capabilities of both snowpack and glaciers in South Asia (Milly et al. 2008), good, reliable water storage will be critical to mitigate the risk of impacts from drought in the agriculture sector (World Bank 2009). Water storage both in aquifers and in surface tanks and ponds requires repair across the western IGP (Planning Commission of India 2008; Planning Commission of India 2013). In addition, many natural water bodies (wetlands and rivers) need to be rehabilitated after years of encroachment and disuse (GDN and Babel Press 2013a).

To effectively mitigate drought risk, the agriculture and water sectors have to deal with old structures left to rot, over-abstraction of groundwater, and a generally poor and unequal management and allocation of water resources. The main strategies to mitigate drought risk through irrigation are dependent on the following:

1. Replenishing aquifers and groundwater
2. Rehabilitating surface storage infrastructure
3. Overhauling the management of both groundwater and surface water
4. Improving water use efficiency

Some details on these strategies is illustrated in the sections below. The signs are positive, as South Asia is moving away from building large irrigation systems and promoting instead the restoration and maintenance of existing structures, improving management, and adopting water-saving technologies and practices (Hasanain et al. 2012).

Solutions: Surface Storage

Natural storage systems, local ponds and tanks, check dams, and other rain-harvesting systems need to be brought back as additional tools against drought. Fourteen Indian states, including Gujarat and Rajasthan, have started a restoration program, and the government has given high priority to the renovation and restoration of tanks and old diversion channels (Planning Commission of India 2008). In areas of Rajasthan (for example, the Alwar district) some centuries-old water reservoirs that had dried up have been restructured, and this has had a positive impact on agriculture production and farmers' livelihoods (GDN and Babel Press 2013a). For the last 27 years, the nongovernmental organization (NGO) Tarun Bharat Sangh has been working on improving storage and distribution, helping to repair and revive rivers[18] and reservoirs, and helping farmers to build canal irrigation as well as drip irrigation systems (GDN and Babel Press 2013a).

In its 12th Five-Year Plan report, the Planning Commission of India (2013) has also revealed plans for a renewed program on Repair, Renovation, and Restoration (RRR) of watersheds. The original RRR program was launched in 2005 with limited success. The novelty of the new proposed plan is a changed focus from repair and maintenance of local storage to protecting surface water sources by restoring the health of catchments: Preventing or reducing soil erosion at the source would limit the extent to which structures and water bodies may be affected by siltation and therefore need maintenance and repair. The report also calls for more participation of WUAs in planning and renovation.

Solutions: Groundwater

Despite continued investments by the Indian government into building of new surface irrigation systems or revitalization of old ones,[19] the area serviced by surface canals has decreased since 1990 while use of groundwater boomed (Shah 2009a). Before the British started developing large canal projects in the 19th century, farmers had favored wells against drought for millennia, as they respond more slowly to a fall in water availability and provide a more reliable source of water year-round (Shah 2009a). The more recent pressure from a growing rural population and booming water demand, along with the availability of small mechanical pumps and government policies, were instrumental to bring back groundwater use. In some parts of India, farmers use groundwater in the command areas of irrigation projects to supplement canal water and maximize agricultural production (Planning Commission of India 2008).

It is likely that demand for groundwater will keep on rising in the IGP, even as a lot of uncertainty remains regarding the future impact of climate change on aquifer recharge (Shah 2009a). Therefore, the relevance of aquifers in the face of weather variability and climate change may be even more critical in the future, particularly in arid and semiarid areas, where surface reservoirs can lose 3 meters of storage per year to evaporation (Shah 2009a).

Shah (2009a) argues that India needs a complete overhaul of the national strategy for water storage, and that with a fraction of the resources the governments puts into development of surface irrigation systems, it would be possible to promote a large-scale plan for recharge of aquifers and make great strides in protecting the country against drought and climate variability. Canals and surface storage and irrigation systems could be reinvented with the specific purpose of enhancing natural groundwater recharge, and this is already happening autonomously (Shah 2009a).

In line with these suggestions, the Planning Commission of India has called for studies into rainwater harvesting and enhanced percolation systems to increase the artificial recharge of groundwater, and it has recognized the role and cost-effectiveness of local independent storage systems (for example, ponds, tanks, check dams) to favor recharge (Planning Commission of India 2008, 2013). The Central Ground Water Board of India (CGWB) prepared a master plan to recharge 36 billion cubic meters of rainwater into groundwater at a cost of 24,500 crore Indian rupees, but aside from pilot projects during the eighth and ninth plans, no real implementation followed (Planning Commission of India 2008). For this reason, in its newly released 12th Five-Year Plan report (2013), the Planning Commission launched a

[18] The NGO helped to revive about 10,000 reservoirs and seven rivers.
[19] An estimated US$20 billion between 1990 and 2007 (Shah 2009a).

new program for watershed restoration and groundwater recharge and proposed a program to map all Indian aquifers in preparation of a National Groundwater Management Programme (Planning Commission of India 2013).

However, fostering groundwater recharge may go to waste without plans to control and prevent further over abstraction from aquifers. In this area, the government is facing the challenge of enforcing rules on millions of farmers, each owning their private tube wells. Several options and ideas have been debated to control water overuse:

- Formulation and implementation of a new groundwater law
- Tradable property rights on water
- Licensing and permit systems to regulate extraction

All these measures have proved very difficult to implement. The Indian legal system has created a situation where groundwater is de facto an open-access resource; the government has worked for decades on a groundwater bill to modify the status quo, but community resistance and the difficulty of enforcing the law on millions of single tube well users has prevented change (Hasanain et al. 2012).

In response, experts from the International Water Management Institute and elsewhere have suggested that the only successful strategy to control demand is to ration the electric power supply (Scott and Sharma 2009; Shah 2009a). The approach has been tested with some success in Gujarat, where rationing farm power supply forced farmers to use both energy and water more efficiently (Shah 2009a). However, in some cases the rationing of electricity has driven farmers to switch to diesel-powered pumps (Sharma et al. 2010), and the measure encounters resistance from policy areas because two-thirds of the IGP population lives on agriculture and represents a huge electoral base (Scott and Sharma 2009). Solutions are still under debate to this day.

Solutions: Water Use Efficiency

The use of improved practices is critical for the sustainability of irrigation in South Asia and therefore of agricultural production in general. The unregulated extraction of both surface and groundwater by millions of smallholders has allowed them to survive, but water overuse has led to loss of water resources also through a series of environmental problems (Shah 2009a). Deterioration of groundwater quality, drying up of wetlands, low flow in rivers and streams during the summer months, soil salinization (especially in the western IGP), salinization of the aquifers, and waterlogging are affecting many areas of the IGP and are the consequence of unplanned intensification of water use (Aggarwal et al. 2004; Shah, Singh, and Mukherji 2006).

Government policies, including the fact that water is essentially free, have eliminated incentives to develop water-use-efficient technologies and practices (Hasanain et al. 2012). Water use efficiency for Indian agriculture, which uses about 80 percent of water resources in the country, is only about 38 percent. This is low compared with 60–80 percent in some developed countries (Planning Commission of India 2013).

Improvements in water use efficiency are critical because besides saving water, they allow energy savings[20] and reduce waste of fertilizers[21] (Planning Commission of India 2008). In both India and Pakistan, efforts are under way to support use efficiency by educating farmers on crop water requirements and therefore on when it is best to apply water to crops during the crop cycle (Hasanain et al. 2012). In India water use efficiency is gaining more attention particularly as water conflicts are growing between agricultural users and between economic sectors (Planning Commission of India 2008).

[20] With less water wasted, there is reduced need for pumping water from aquifers.
[21] This is because of reduced runoff and leaching.

Laser land leveling is one of the methods in use in South Asia to increase water use efficiency and that can reduce both waterlogging and salinity (Hasanain et al. 2012). The furrow-irrigated raised bed system and direct seeded rice (wet or dry) are other options that may save water and reduce waterlogging, thanks to better soil structure and surface drainage. However, adoption of these technologies is still low, due mainly to the costs of implementation (Hasanain et al. 2012; Chauhan et al. 2012).

Furthermore, at the moment South Asia still has inadequate government support for research and development and limited irrigation technology choices available to improve water use efficiency in a cost-effective manner (Hasanain et al. 2012). There are, however, some regional differences. In India drip irrigation is expanding quite rapidly due to government subsidies (Hasanain et al. 2012); still, out of 69 million ha of net irrigated area, only 0.5 ha are currently under drip irrigation and 0.7 ha under sprinkler irrigation (Planning Commission of India 2008).

In Pakistan, in the south province of Sindh, a dry climate combined with inefficient and unequal distribution of water often results in water shortages. Farmers at the tail end of irrigation canals cannot be sure to get their due share because upstream farmers often get more than they are allocated. Drip and sprinkle systems could be a precious solution, and some NGOs are providing help, but medium and smallholder farmers often face constraints that prevent them from investing (GDN and Babel Press 2013a).

These well-known constraints, such as lack of secure property rights and reduced access to credit, also affect those farmers that rely on tube wells; despite water shortages and increasing costs due to the need of deepening wells, they are unable to invest in technologies that could improve water use efficiency.

Both the government and private sector can have a role in changing the circumstances faced by smallholder farmers. This starts with offering education to farmers to increase their technical and financial skills and to inform them about the potential of new technologies, with the intent of changing their perception and risk attitude. This approach helped to spread laser land leveling in Punjab (Hasanain et al. 2012). Changes in the price of energy may also contribute to a change in attitudes (Hasanain et al. 2012).

Solutions: Better Management

There is an increasing difference between the irrigation potential created, in terms of area that can be irrigated and the area effectively irrigated. In India the share of cultivated area equipped for irrigation has been growing since then 1970s, but the share of this area that is actually irrigated has remained constant (Figure 3.3). The Planning Commission of India stated that the difference between the irrigation potential created and the potential actually utilized (in terms of hectares covered) is increasing. In the analysis, the main causes are the unequal distribution of water (between farmers at the head of the canals and at the tail end) as well as design and management problems (Planning Commission of India 2008)

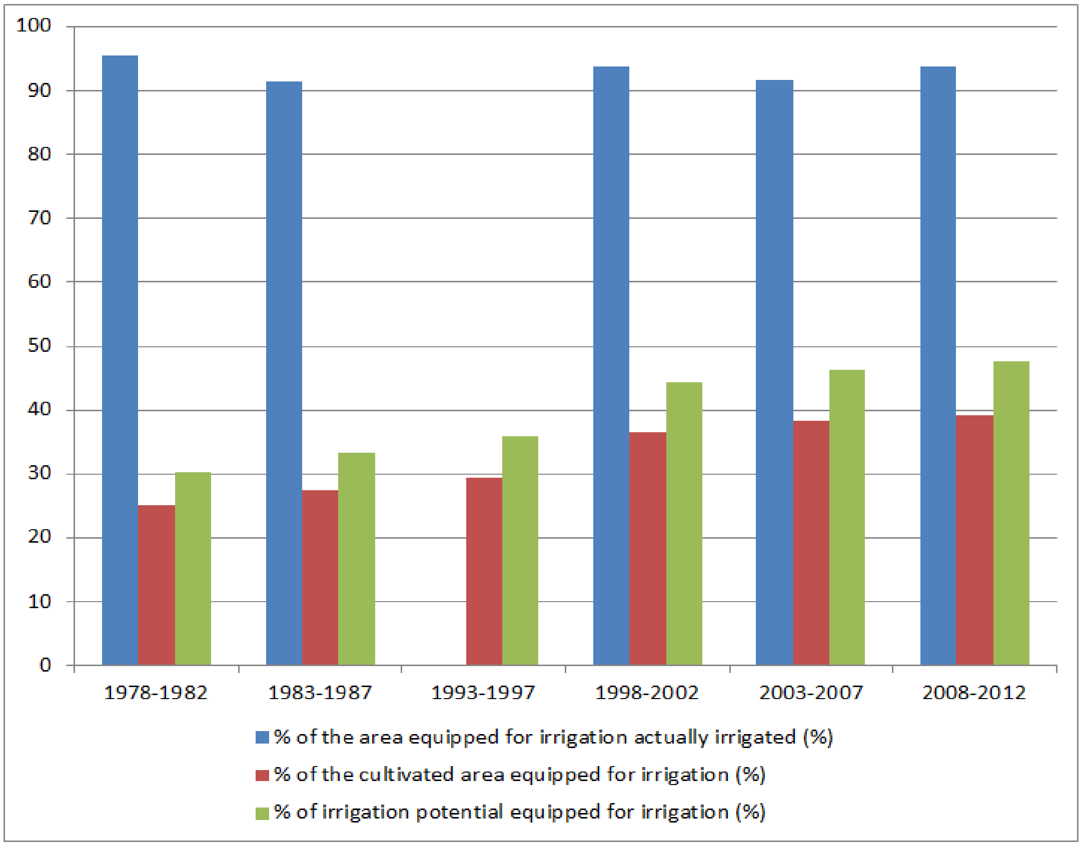
Consensus is mounting that empowerment of WUAs and fostering these and other farmers’ associations will improve both management of surface water and water use efficiency, and that farmers should be involved in irrigation projects, starting from the planning and implementation stages (Planning Commission of India 2008; GDN and Babel Press 2013a).

Evidence also exists that farmers’ participation in operation and maintenance of irrigation schemes through WUAs or other farmer organizations improves the overall quality of irrigation, in terms of performance, efficacy, and longevity of the whole system, compared with a centrally managed top-down approach (Hasanain et al. 2012). WUAs and other farmer organizations appear to nurture a sense of ownership that fosters participation and improves the rate of collection of member fees. This is critical as the fees are then used for operation and maintenance (Hasanain et al. 2012).

The overall impact of these organizations is difficult to assess due to differences in the level of government support and effective implementation both between and within countries in South Asia. Hasanain and colleagues (2012) assert that WUAs and farmer organizations in Haryana are established only superficially, whereas in Gujarat they are better organized and effective. In general, experts agree that reinforcing these institutions and favoring participative decision-making and operation from farmers has positive effects on the performance of irrigation schemes (Hasanain et al. 2012; Shah 2009a).

In its 11th Five-Year Plan, the Planning Commission of India (2008) acknowledged the limits of a centralized management approach and recognized the role of WUAs toward the achievement of a more equitable and efficient use of water resources. The report indicated that “system maintenance and revenue realization should be handed over to beneficiaries groups or WUA” (Planning Commission of India 2008, 54), and set the goal of covering “the entire command of all major and medium projects with WUAs by the end of the Eleventh Plan” (that is, 2012).

Figure 3.3 Comparison between area actually irrigated and area equipped for irrigation



Source: FAO (2013).

Adaptation Option: Access to Food

Supporting a stable food production is critical to ensure food availability in arid lands and across all developing countries. However, the ability of households to obtain food depends also on food prices, presence of markets, and employment opportunities.

Access to Food—East Africa

In the Horn of Africa, drought strongly affects agricultural production, especially in arid and semiarid lands. In some cases these impacts are compounded by national and regional economic policies, such that drought is ultimately felt by the entire population in the form of higher food prices (World Bank 2011). In Kenya, national policies are maintaining high maize prices, thereby favoring large producers and damaging both consumers and those small producers that are net buyers of maize. Local reforms will be necessary to control the price of food items, but change is hampered by political wrangling (World Bank 2011).

New analysis on price volatility for major food staples in SSA also suggests that some of the methods used in the region to stabilize prices are not being successful (Minot 2012). For instance the data show that price volatility for maize is significantly higher in those countries where large state-owned enterprises intervene in the market by buying or selling commodities in an attempt to stabilize prices. Similarly, prices of commodities for which countries are self-sufficient are more volatile than the prices of tradable goods, supporting the notion that food self-sufficiency is not a winning strategy, and that trade can be helpful to stabilize prices (Minot 2012). Therefore, changes must be made at the regional level to stabilize prices, such as limiting or lifting tariff, nontariff (bureaucratic), or both trade barriers between countries, which contribute to price hikes for major commodities like maize.

In addition, grain storage, in the form of a physical food reserve in public or private facilities or a virtual reserve as proposed by von Braun and Torero (2009) or both, would help prevent the price fluctuations caused by trade policy interventions like exports bans and tariffs or import subsidies (World Bank 2011; von Braun and Torero 2009).

At the same time, a stable source of income is essential to maintain households' purchasing power and ensure their access to food. Livelihood diversification is one of the main strategies to ensure income. In the arid and semiarid areas of Kenya, farmers may resort to diversifying crops during the year. Pastoralists may use weather-indexed insurance, as well as fodder production and haymaking, as strategies to diversify their income (World Bank 2011).

Access to Food—Indo Gangetic Plains

In Rajasthan, adaptation to increasing frequency and severity of drought, and consequently the need to change cropping patterns so as to control water use, was successfully combined with the need to increase farmers' economic stability. The NGO KIGS[22] introduced in Rajasthan the cultivation of medicinal plants, which can provide villagers with an additional source of income. A specific plant, Sonamukhi (*Cassia angustifolia*), needs little water or labor and can be grown in wastelands, with the double effect of rehabilitating these soils and not occupying land necessary for the cultivation of crops (Chatterjee, Chatterjee, and Das 2005).

Livestock is also an important source of livelihood for people in the arid Rajasthan. Although the price of feed and fodder usually increases during droughts, therefore compounding the impact of drought on cattle, both state and national government have enacted policies to maintain prices of food grain and to support wages (Rathore 2005). This is mainly attained through the public distribution system which established a network of Fair Price Shops across India providing essential commodities on a regular basis and at reasonable prices (Rathore 2005). The effectiveness of the system in improving nutrition levels of the poor and combating inflation is debated, and its impact appears to be proportional to its geographical

[22] www.kigs.org.

presence. However, its critical role in times of drought crisis for distribution of food grain and commodities to the population is recognized and has had positive effects in Rajasthan (Rathore 2005).

Adaptation Options—Utilization of Food

"Though causal links [may be] difficult to establish at a population level, droughts set the conditions for a wide range of nutritional, infectious, psychological and other health consequences that usually occur after a severe disruption of basic economic systems" (Rabie et al. 2008, 9). *Utilization of food* refers to the physiological or biological ability of people to derive full sustenance from the food available, which depends on the health of the individual, and it is therefore linked to issues of public health and exposure to vector-borne diseases.

Aside from effects on agricultural productivity, water scarcity also directly affects the quantity and quality of drinkable water, diminishes air quality due to increasing dust and particulates in the air, and can increase the incidence of illness and disease (Kalis, Miller, and Wilson 2009). Negative health effects can also originate from wildfires and heat waves associated with drought events. Wildfires can irritate the lungs, "thereby exacerbating chronic respiratory illnesses and increasing the risk for acute respiratory infection (for example, bronchitis and pneumonia)" (Kalis, Miller, and Wilson 2009, 11). Heat waves can cause injury (death or illness) directly through heat stress, heat stroke, or exhaustion or, more frequently, indirectly by aggravating preexisting medical conditions sensitive to heat stress, such as cardiovascular, cerebrovascular, renal, respiratory, and mental diseases (Rabie et al. 2008).

In addition, prolonged drought can cause both surface and groundwater to become polluted and contaminated with toxic chemicals and with vectors of infectious diseases, exposing the population to a higher risk of diarrheal diseases (Rabie et al. 2008). The shrinking of water bodies can create conditions of stagnating water and provide new breeding grounds for mosquitoes; depending on the region this may be conducive to outbreaks of malaria (Kalis, Miller, and Wilson 2009). Although all health effects impair the ability of an individual to obtain full physiological benefit from the available food to some degree, exposure to infectious and vector-borne diseases has a more direct detrimental effect.

Given the labor-intensive nature of agriculture in developing countries, part of the long-term coping mechanisms will have to do with monitoring and managing the health impacts of extreme events (World Bank 2009), while also building resilience in the population in terms of overall health and nutrition (Headey and Kennedy 2012).

Utilization of Food—East Africa

In Africa, proper understanding of the various impacts of climate change and droughts on human health is still thwarted by lack of detailed scientific evidence (Byass 2009).

Because of the impact of droughts on incomes and assets, during drought emergencies fewer resources are available for healthcare, exactly at a juncture where healthcare would be most needed due to malnutrition and the associated ailments, including higher vulnerability to diseases.[23] "Lack of water and population displacements, which result in precarious sanitation, further increase the risk of communicable diseases such as cholera, typhoid fever, diarrhea, acute respiratory infections and measles."[24]

A vicious cycle is in place between poverty, general health status, infectious diseases, and malnutrition. The nations of the Horn of Africa have weak healthcare systems, with limited medical supplies and human resources and low immunization coverage (WHO 2011). They have also limited access to safe water, especially in rural areas (Figure 3.4) and very low access to improved sanitation (Figure 3.5). Malnutrition resulting from drought events weakens the body, making it more susceptible to contracting infectious diseases, and the effects of malnutrition are compounded by poor starting health conditions. As illustrated in 2010–2011 during the drought crisis in the Horn, populations under stress for

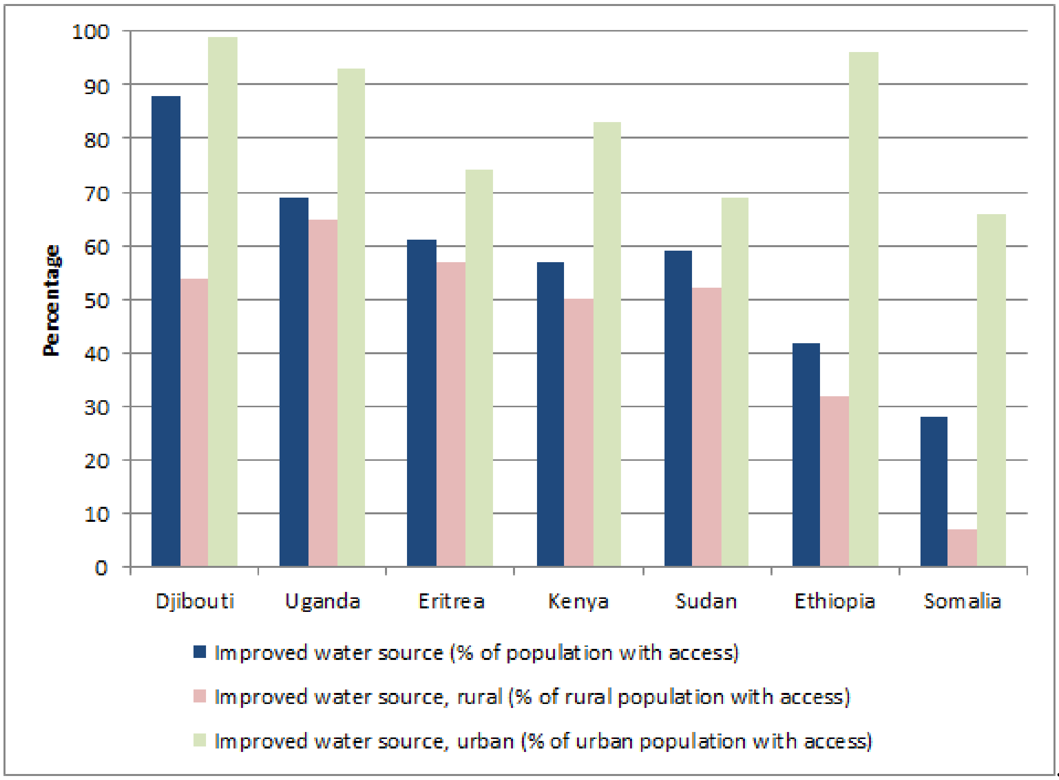
[23] http://www.who.int/hac/crises/horn_of_africa_communities/en/index.html, accessed January 2013

[24] http://www.who.int/hac/crises/horn_of_africa_communities/en/index.html; accessed January 2013.

lack of food and water, displaced and lacking access to basic sanitation, become more susceptible to diseases (WHO 2011).

The World Health Organization (WHO) has prepared a number of guidelines and reports to help assess and manage public health conditions during drought emergencies in the Horn of Africa.[25] However, general health services must be bolstered across SSA to increase the baseline resilience to weather shocks. The region especially requires investments toward immunization, emergency care, reproductive services, and nutrition services, along with investments in education (Headey and Kennedy 2012).

Figure 3.4 Share of population with access to an improved water source in East Africa, 2008

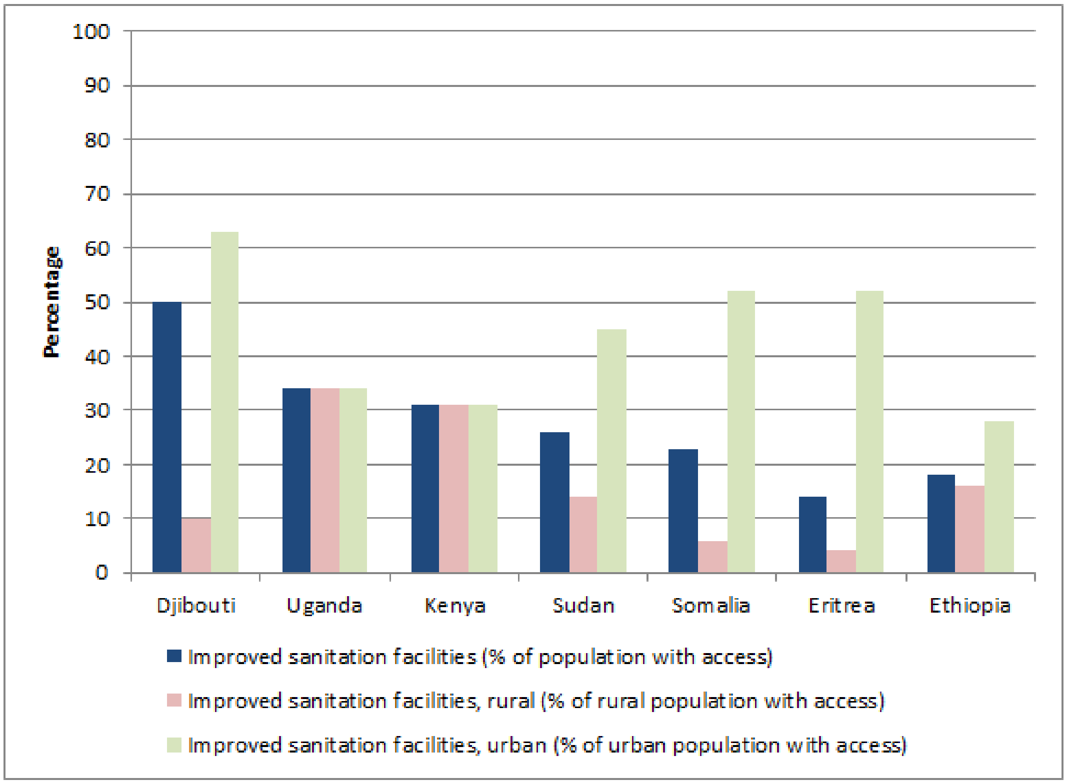


Source: JMP (2013).

Notes: Access to an improved water source refers to the percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 liters a person a day from a source within one kilometer of the dwelling.

[25] See http://www.who.int/hac/techguidance/en/ and http://www.afro.who.int/en/clusters-a-programmes/ard/emergency-and-humanitarian-action/highlights/3067-public-health-risk-assessment-and-interventions-the-horn-of-africa-drought-and-famine-crisis.html (accessed January 2013); and WHO (2011).

Figure 3.5 Share of population with access to improved sanitation facilities in East Africa, 2008



Source: JMP (2013).

Notes: Access to improved sanitation facilities refers to the percentage of the population with at least adequate access to excreta disposal facilities that can effectively prevent human, animal, and insect contact with excreta. Improved facilities range from simple but protected pit latrines to flush toilets with a sewerage connection. To be effective, facilities must be correctly constructed and properly maintained.

Utilization of Food—Indo-Gangetic Plains

In Rajasthan water needs are met by hand pumps and open wells. As drought and low rains reduce the recharge of aquifers, drinking water often becomes unsafe (mixed with mud and with higher concentrations of chemicals) (Chatterjee, Chatterjee, and Das 2005). This compounds other health impacts originating from the restriction of domestic water availability (Rathore 2005).

A case study on maternal healthcare reports that because women in most households are responsible for gathering water, fodder, wood for fire, and forest products, they are the most affected when droughts strike. In addition, young brides usually eat last (and least) in the family, especially during times of drought and food scarcity (Iyengar, Iyengar, and Gupta 2009). In 2003 the maternal mortality rate in Rajasthan was 445 per 100,000 live births, higher than the national average (Iyengar, Iyengar, and Gupta 2009).

In this state, the impact of droughts on income has a direct effect on education and access to healthcare. Many villages do not have local doctors or medical facilities, and trips to other villages or hospitals are necessary. Savings are usually gathered in preparation of these occurrences, but when droughts affect production year after year, savings are eroded and with them the affordability of both trips to the hospital and treatment (Chatterjee, Chatterjee, and Das 2005).

Adaptation Options—Financial Vulnerability

As pointed out in the literature, including some reviewed in this report, fear that the unpredictable vagaries of the climate will severely damage crop production makes farmers in arid and semiarid areas extremely risk averse. This attitude is further strengthened by the widespread difficulties in accessing markets, credit, and training. The direct result is low investments, a continuous underachieving production, low assets and income, and persisting poverty, which reinforces lack of opportunities and continuing poverty.

Weather insurance may be a powerful help to reducing risk, thereby creating the conditions for investment in productivity-enhancing actions, and thus breaking the poverty trap.

Weather Index Insurance

The key characteristic of insurance as a safety net may be its role in changing the attitude of people toward risk. In the insurance field, moral hazard is a well-studied aspect of human behavior. The term indicates that people who have some sort of insurance are more prone to take risks because they know that they are at least in part protected from damages. Moral hazard is commonly regarded as a negative by-product of buying insurance. However, among smallholder farmers in Africa as well as in South Asia, moral hazard is what insurance hopes to promote. Exposed to high levels of risk, farmers do not invest in inputs (for example, irrigation, fertilizers) or seeds, because all they have could be wiped out by unpredictable weather events; as a result, their productivity stays low and their income stagnates. Buying insurance allows farmers to look more positively at their prospects and invest in practices and inputs that can improve production and have the potential to break the vicious poverty cycle.

Weather insurance is hailed as a potential solution to respond to drought events in many contexts, but demand for it is dependent on several factors. For instance in India, better-off farmers seem to have sufficient access to insurance via informal mechanisms. On the other hand, poor farmers are highly credit constrained and cannot afford to buy insurance; therefore, demand for insurance can be expected only if the coverage offered has distinct advantages compared with other independent methods, and if the coverage is provided at very low cost (Binswanger-Mkhize 2012). These findings might be extrapolated to poor farmers in SSA, as they are generally even more cash strapped compared with Indian family farmers (Binswanger-Mkhize 2012).

For weather insurance to be offered and to have a large impact, it needs to reach a large pool of people; this requires overcoming several barriers:

1. Barriers to create supply: These include mainly transaction costs related to finding and reaching customers, selling policies, collecting payments (premiums), and verifying claims.
2. Barriers to create demand: Premiums are often too costly for poor farmers, so demand can be limited to wealthy individuals. Lack of education and understanding of how the insurance system works thwarts adoption. Bad experiences can tarnish the image of insurance for farmers—that is, they do not trust "insurance people."
3. Other barriers: Linked to the issue of trust is the fact that convincing farmers and building trust takes time and it is costly.

In East Africa and India, past and more recent experiences have been at least partially able to tackle some of these barriers and reach farmers.

Experience in the Horn of Africa

In East Africa pilot projects on weather index insurance against the impacts of drought have been run in Ethiopia and Kenya. Two of these projects, Horn of Africa Risk Transfer for Adaptation (HARITA) in Ethiopia and the Kilimo Salama project in Kenya, are still ongoing (Table 3.9).

Table 3.9 Examples of drought index insurance in the Horn of Africa

Name of insurance	Country	Launch year
HARITA	Ethiopia	2007
Kilimo Salama	Kenya	2009
Haricot bean insurance	Ethiopia	2009

Source: WFP and IFAD (2010).

In Ethiopia the first example of index insurance was a one-year pilot project developed in 2006 by the government in collaboration with the World Food Programme. It was designed to ensure against the risk of a national-level drought-induced catastrophe (WFP and IFAD 2010). The development of an effective drought index (the Ethiopian drought index, EDI) thanks to the collaboration between the government and the National Meteorological Agency (NMA), allowed to insure the risk on the international financial market. The goal was to insure a group of so-called transiently food-insecure people, Ethiopians who were not normally food insecure but could risk becoming chronically food insecure in the aftermath of droughts (or floods) (WFP and IFAD 2010).

The haricot bean index insurance, a short project implemented in 2009, provided insight and lessons about the weather index system. It convinced the government that weather insurance could work in Ethiopia, but also identified areas that needed intervention as a basis for future success (WFP and IFAD 2010). Under technical supervision from the WFP, the Nyala Insurance Company (NISCO) designed insurance contracts and then promoted and sold them through LAFCU, the Lume Adama Farmers' Cooperative Union. Because the cooperative was already trusted by farmers as a delivery intermediary for seeds and fertilizers, its involvement was critical to ensure farmers' participation in the program. The cooperative bought drought insurance for farmers growing haricot beans, based on a rainfall deficit index. When drought hit, in 2009, indemnities were paid to LAFCU, which then distributed the payments to the farmers. The program involved only 137 farmers. It became clear to the government that expansion of such programs would need financial support to both insurers and farmers' unions, and although farmers in the pilot understood the insurance policy and its benefits, enlargement of the program would require providing training to farmers as well as to unions and insurers.

The HARITA program was launched in 2007 as a "partnership between Ethiopian farmers, Oxfam, the Relief Society of Tigray (REST), Nyala Insurance Share Company (NISCO), Debit Credit and Savings Institution (DECSI), Mekelle University, the International Research Institute for Climate and Society (IRI), Swiss Re, the Rockefeller Foundation, and six other organizations, including a farmers' cooperative, local government agencies, a local agriculture research organization, and global legal experts."[26] Financial support for the project, which is continuing and developing to this day, comes from the Rockefeller Foundation and Swiss Re. The strength of the program is the use of established relationships in the country. The participants understood the importance of leveraging the local experience on the ground: Oxfam has a long tradition of working in Ethiopia. DECSI is one of the largest microfinance institutions in Ethiopia, with strong relationships with the local communities; it was chosen as the intermediary selling insurance on behalf of NISCO.

Several approaches to providing drought insurance to the poorest have not been effective, owing to high administrative costs and the inability of cash-poor smallholders to afford premiums. The HARITA program also linked with the Ethiopian Productive Safety Net Programme (PSNP), by allowing cash-constrained farmers to partially pay their premium through labor. Oxfam America worked together with the Relief Society of Tigray and the government of Ethiopia to build an insurance-for-work program, facilitated by the government experience with the food-and-cash-for-work PSNP already in place.

As an additional risk-reduction layer, activities performed under the program include work that promotes climate resilience, such as small-scale water harvesting, improved soil management and conservation, and agronomic practices to increase soil moisture retention, as well as other agricultural

[26]http://www.oxfamamerica.org/publications/horn-of-africa-risk-transfer-for-adaptation-harita-quarterly-report-october-20112013december-2011, accessed October 2012.

measures that help to restore the fertility of degraded soils (Oxfam America 2011). As an alternative, farmers are given the choice of bundling the insurance with credit, therefore enabling them to buy seeds and inputs while reducing the risk of losing the whole investment in the event of drought [27](Oxfam America 2011). Technically the partnership has produced an effective rainfall index and has succeeded in reducing basis risk by using different techniques and resources to increase the coverage of sparse rainfall datasets. Payments are released automatically when rainfall drops below a certain threshold during a drought event. Transaction costs, which are one of the main barriers to generation of offer (that is, supply), are controlled by the use of intermediaries such as cooperative unions, microfinance institutions, and agrodealers. Kilimo Salama, an ongoing index-insurance program in Kenya and the largest in Africa,[28] found an innovative way to use technology to further reduce the transaction costs faced by insurance agents.

Kilimo Salama, a Swahili term for "safe agriculture," was launched by a partnership between UAP insurance and the Syngenta Foundation for sustainable agriculture. Partners in the endeavor are the agribusiness MEA Limited, Syngenta East Africa, the telecommunication company Safaricom and the NGO AGMARK.[29] Wheat and maize farmers insure their farm inputs (for example, seeds and fertilizers) against both drought and excess rainfall. The project uses the collaboration of agrodealers and stockists to sell the insurance, and payment for premiums was restructured to make it affordable for farmers: The premium is 10 percent of the value of the product purchased (input), but the farmer pays half, that is, 5 percent of the value of the product (on top of the cost of the input itself), and MEA and the Syngenta Foundation cover the other 5 percent. The system is based on numerous weather stations equipped with global positioning systems and solar panels, which transmit data about rainfall. The weather station measurement determines if there is a payout or not—it measures rainfall and other weather parameters for an agroclimatic zone of about 15 square kilometers, and all the farmers within this area will receive payment based on that particular weather station readings—so the farmers are insured "under that particular weather station."[30] When a rainfall threshold is passed, payments are automatically released, for a certain percentage of the cost of the inputs purchased, based on the severity of the weather event.

The defining characteristic of Kilimo Salama is the technological solution that allowed to minimize transaction costs: mobile phones. All insurance contracts are sold by UAP to farmers in the stores, agrodealers and stockists, where farmers buy seeds, fertilizers, and pesticides. Thanks to the partnership with Safaricom (mobile service provider), all contracts are stipulated by agrovets and stockists via phone through short message service (SMS); premiums are transferred again via SMS (M-Pesa, the system of phone payment already established in Kenya) from agrovets to the insurance company, and payments following a weather event are released again through the phone system.

Farmers with as little as 1 hectare of land can insure their inputs, and in addition, based on the data from weather stations, Syngenta sends SMS messages to the farmers providing advice on what practices to use to limit losses, therefore protecting their investment, while also helping farmers reduce risk of weather impacts.

Thanks to the intermediation of local agrodealers and unions, the projects in Kenya and Ethiopia have also tackled the issue of trust, by having people familiar to the farmers explain and sell the product. In addition, in Kenya, the use of M-Pesa, a system every Kenyan is familiar with, gives farmers trust that their money is not being stolen or lost. However, a lot of money still goes into paying trainers working with farmers and radio and telephone help systems to inform about insurance. These costs may go down if the programs are scaled up.[31]

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[27] That is, they "collateralize credit with insurance."

[28]http://opinionator.blogs.nytimes.com/2011/05/09/doing-more-than-praying-for-rain/; accessed October 2012.

[29]http://www.syngentafoundation.org/index.cfm?pageID=674; accessed October 2012.

[30]http://kilimosalama.wordpress.com/; accessed October 2012.

[31]http://opinionator.blogs.nytimes.com/2011/05/09/doing-more-than-praying-for-rain/; accessed October 2012.

Experience in India

The greatest success for weather index insurance for number of covered farmers is in India. Table 3.10 summarizes some of the major insurance programs in the country. Since the late 1980s, farmers who take loans from government credit institutes have been required to buy a subsidized insurance plan against drought, the National Agricultural Insurance Scheme (NAIS). However, the plan has been mired in problems; in Haryana the state government put in place the NAIS only from the 2004 kharif season onward (Planning Commission of India 2009), and nationally only 15 percent of the farmers actually buy into the scheme (WFP and IFAD 2010).

Table 3.10 Examples of drought index insurance in India

Name of insurance	Launch year
NAIS	late 1980s
ICICI Lombard	2003
ITGI	2003
Varsha Bima	2004
Weather-based crop insurance	2007

Source: WFP and IFAD (2010).

In 2003, the insurance company ICICI Lombard, supported by the World Bank and International Finance Corporation (IFC), set up a pilot rainfall insurance scheme in Andhra Pradesh. The program was in collaboration with Basix, a microfinance and livelihood support institution already trusted by farmers' groups. The insurance was against drought and excess rainfall; it had accessible prices, and was delivered through a well-established banking network with good links to farmers. Although private companies in India have a history of preferring to target larger-size farmers, ICICI Lombard, thanks to involvement of Basix and to a diversified portfolio, which included extension services, was able to reach low income farmers. However, the insurance was not linked to credit, and the size of the customers' basin remained low (about 115,000 farmers in 2007/2008).

In the same year, another 70,000 farmers were covered under the ITGI program, a joint venture between Tokyo General Insurance Company and the Indian Farmers Fertilizer Cooperative, which used its network to reach and sell drought insurance to farmers (WFP and IFAD 2010).

In 2004, the Agriculture Insurance Company of India (AIC), a public company founded by the government one year before to manage the NAIS, started to deal in index insurance. This move was due both to the shortcoming of the NAIS, whose payouts are triggered when yields are below a certain average yield for the area[32] and to the direct priorities manifested by farmers. AIC offers several weather index products, some of which are related to insurance against drought. One is the Varsha Bima[33] rainfall insurance, the longest-running index insurance product of the portfolio, which provides payouts if rainfall is below a threshold level for a certain area (deficit rainfall). More successful in terms of number of farmers insured are two weather-based crop insurance schemes (known as WBCIS) started in 2007 by AIC (WFP and IFAD 2010).

Credit constraint and other barriers are still difficult to tackle in East Africa and India. As a result, demand for insurance, either on individual crops or an index-based insurance, is still low. Safety nets such as some sort of employment guarantee scheme as used in India and Ethiopia would probably be preferred by poor farmers (Binswanger-Mkhize 2012).

32http://www.aicofindia.com/AICHindi/General_Documents/Product_Profiles/VB_FAQ.pdf; accessed November 2012.
[33]http://www.aicofindia.com/AICEng/Pages/Product_Profile/Present_VarshaBeema.aspx.

Public Works Programs

Given the issues with insurance supply and demand illustrated above, researchers often suggest that alternative forms of support and safety nets, such as social networks, community support, and public works programs, may have a larger positive effect as relief during drought and other times of crisis (Binswanger-Mkhize 2012; Del Ninno, Subbarao, and Milazzo 2009; Hazell and Hess 2010).

Public works programs offering a source of income through temporary jobs are implemented across the world. In some instances, the type of job offered may bring additional public goods to the community: For instance, the job may relate to mitigation of weather shocks through changes in agricultural practices, or it may lead to secondary employment opportunities (Del Ninno, Subbarao, and Milazzo 2009). These programs are prevalent in low-income countries. The largest number of participants are in South Asia and SSA, where they get generally activated for poverty relief in case of some economic crisis, natural disaster, or weather-induced shocks, when incomes may be dropping (Del Ninno, Subbarao, and Milazzo 2009).

Bangladesh and India have long-standing programs of food-for-work at both the state and national levels. In India such programs have been regularly used to buffer the effects of drought, and they were able to protect the poor during the massive drought of 1987 (Del Ninno, Subbarao, and Milazzo 2009). The National Rural Employment Guarantee Scheme (NREGS) extended by the government of India to the entire country can support public works and watershed programs (India, Department of Agriculture and Cooperation 2009, 63).

In Ethiopia, the government has instituted the Productive Safety Net Programme (PSNP) to tackle poverty in drought-prone areas. The program is based on public works, particularly soil and water conservation activities, which have already brought benefits to the environment and to the communities depending on it: Water conservation has increased groundwater recharge as well as productivity in some areas (Del Ninno, Subbarao, and Milazzo 2009). Other activities including infrastructure building and repairs (for example, roads) are generating additional income by helping communities reach markets (Del Ninno, Subbarao, and Milazzo 2009).

4. CONCLUSIONS

Analysis of data from Ethiopia and India suggests that in areas "where drought is a major risk, it is also the single most important factor in impoverishment—outstripping for example ill health and dowry payments" (Shepherd et al. 2013, x). Therefore, implementation of disaster risk management is critical to successfully eliminate poverty and improve food security in these regions.

The goals of this report were to review the drivers of vulnerability to drought in East Africa and in the western Indo-Gangetic Plain of South Asia, to explore options to increase the resilience of farming communities, and to present both opportunities and obstacles to the development and adoption of drought risk reduction measures.

Drought risk reduction must focus not only on saving lives but also on saving livelihoods, by reducing vulnerability to hazards and by supporting asset building before and after an extreme event has taken place (Shepherd et al. 2013). Moreover, because droughts in East Africa and IGP are not necessarily localized in space and time, as they may be more of a recurrent phenomenon, disaster risk management should be emphasized as an integral part of development work.

By now, we possess a wealth of evidence, accumulated from modeling studies and work in the field, about the benefits of different agricultural technologies and practices in mitigating drought (Rosegrant et al. 2014). Complementary interventions, like safety nets and insurance programs, are also proving to be effective in building resilience and reducing drought risk. More and more often, national and local governments have access to relevant knowledge, information, and tools and techniques—but this material needs to be delivered to the places and people who need it most. Research shows that in SSA and in South Asia, access to innovation, knowledge, and input and output markets continues to be the most important constraint to investments in agriculture, and therefore to development of irrigation and adoption of other agricultural practices relevant to drought risk reduction (GDN and Babel Press 2013b).

Governments, NGOs, the private sector, and aid agencies continue to have very important roles to play to overcome these constraints and increase the resilience of farmers to drought events. Governments can set up farmer schools and must invest in infrastructure, organize and modernize extension services to promote the most appropriate resource-saving practices, and improve the multiplication of stress-resistant seed varieties, in cooperation with the private sector.

We have some encouraging examples. The government of Ethiopia put together the PSNP social protection scheme, helping food-insecure households to build their assets, by providing education on new cultivation techniques and production diversification, and by setting up a monitoring system that checks whether households are building both individual and communal assets. The government in Kenya was able to coordinate with the private sector to multiply seeds, and facilitated the award of loans and credit by building the knowledge and skills[34] of farmers (GDN and Babel Press 2013d).

In many instances, especially where the government reach was inadequate, NGOs have stepped in to support the diffusion of improved seeds, instruct farmers on crop and livestock diversification, and promote the adoption of new agricultural techniques and practices through farmers' education programs. Moreover, across South Asia and SSA, NGOs, alone or in cooperation with financial institutions, government bodies, and international aid organizations, are tackling farmers' constraints by using microfinancing to push forward adoption of fertilizers and improved crop varieties. In some instances they offer packages that include crop insurance; some work is also being done on adding items such as chlorine dispensers for clean drinking water, a useful step toward tackling public health issues that increase vulnerability of farming communities (Thurow 2012). And governments, NGOs, the private sector (for example, cell phone communications), and financial institutions have come together to facilitate the diffusion of weather index insurance.

In India the private sector is intervening directly in some situations to fill some of the knowledge and technology gaps by providing farmers with training on new practices. They invest in capacity to

[34] This reduces the risk carried by financial institutions.

ensure a steady flow of product for their commercial activities, and in doing so they also facilitate the farmers' access to markets (GDN and Babel Press 2013c).

These are examples of how different institutions can help farmers adopt best practices and technologies, improve their productivity, build their assets, and thus dramatically reduce their vulnerability to shocks. But agriculture is still a high-risk endeavor in both South Asia and SSA. More work is needed in many areas; for instance, cooperation with the private sector for seed multiplication is still inadequate, and technology and knowledge dissemination must be strengthened.

One of the ways forward may be to redirect some of the financing for food aid and post disaster relief to investments in development and resilience building. The example of MERET in Ethiopia shows that a gradual transition between the two is possible. Although the use of food aid to encourage work is still controversial, the experience of MERET demonstrates that the approach can be used to promote development and build resilience against drought; food aid can then be phased out in exchange for more technical assistance and for loans (Nedessa and Wickrema 2010).

Institutions like governments, NGOs, and international organizations may help build farmers' resilience also through another route. Collectivization, the formation of farmers associations, and in general the formal or informal organization of individuals in a group of some kind, has historically helped farmers to manage risk, including by facilitating the adoption of new technologies and new skills, and helping with access to markets and credit, thereby promoting the accumulation of assets and reducing vulnerability to shocks (Bernier and Meinzen-Dick 2014). However, these organizations are often less able to cope with covariate shocks[35] such as droughts or floods. Research on collective action and local groups suggests that external support, such as links with higher-level organization (for example, government, international organizations, NGOs) may allow groups to increase their efficacy (Di Gregorio et al. 2012).

Drought risk reduction and improvement of resilience is a process; as such it requires long-term commitments from governments and from the research and development community. Single projects cannot transform a society and its resilience. What is needed is long-term support to learning and capacity building, and investments to cultivate the capacity for disaster risk reduction across farming communities. Building social capital and changing behavior are critical bases to ensure resilience against weather shocks for the long term.

[35] Covariate shocks are those shocks that typically affect many members of the community at the same time, making it more complicated for people to have the resources to help one another.

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