CHAPTER 22

c0022 # BUNDLING DROUGHT TOLERANCE AND INDEX INSURANCE TO REDUCE RURAL HOUSEHOLD VULNERABILITY TO DROUGHT

Travis J. Lybbert and Michael R. Carter
Department of Agricultural and Resource Economics, University of California, Davis, CA

CHAPTER OUTLINE

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s0010 ## 22.1 INTRODUCTION

p0055 Drought is fundamentally a weather event characterized by below normal precipitation, but its human impacts are much more complex and nuanced than this simple climatic definition might suggest. In human welfare terms, drought effects are shaped by the geophysical, agronomic, social, economic, and political features of a given context. Among many of the world's poor, frequent drought combined with an unfortunate confluence of these mediating features makes drought one of their most worrisome perennial concerns. In rural rainfed settings, drought can damage or destroy crops and livestock, causing hunger and illness and reducing household food security. These immediate effects can induce persistent harm by triggering costly coping responses such as liquidating assets, skipping meals, and

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choosing inferior foods that can have persistent effects and reduce long-run household welfare. Moreover, it is not just the occurrence of drought that carries a hefty burden; for vulnerable households the very threat of drought can prevent them from taking full advantage of their resources and keep them poorer than they otherwise might be.

p0060 Since World War II, development and relief efforts have largely aimed to provide frontline responses to weather shocks such as floods and droughts and, more recently, to reduce household vulnerability to these shocks. While the essence of these policy objectives remains the same, climate change projections of more extreme and more frequent weather events in many poor places have added new urgency to mitigating the weather risks borne by the rural poor. In the case of drought risk, a flurry of innovative interventions to reduce these risks has attracted substantial attention and funding from both the public and private sectors. Drought tolerance (DT) in crops and index insurance (II)—agronomic and financial innovations, respectively—have generated particularly high expectations.

p0065 This chapter argues that some of the hype around DT and II should be moderated by an appreciation of their respective limitations. In isolation, DT may protect against crop losses due to moderate drought but leave farmers' exposure to extreme drought risk virtually unchanged. While II might provide good protection against both moderate and severe drought, rural households may be unwilling to pay actuarially fair prices to access II that offers complete protection.

p0070 By exploring a simple complementarity between the two, this chapter demonstrates that properly bundling DT and II may restore a good deal of these innovations' promise. In particular, when bundled with DT that protects against moderate drought, II could be redesigned to cover only the kind of severe drought events that might overpower any protection offered by DT. Such an extreme event II product could be offered at substantially lower prices, making them more accessible to poor farmers. Further, an increase in II demand due to the implicit subsidy provided by DT may improve the long-run viability of such emerging financial markets.

s0015 22.2 DROUGHT RISK, VULNERABILITY, AND DEVELOPMENT INTERVENTIONS

p0075 The United Nations recently estimated that 1.5 billion people were vulnerable to drought (United AU:1
Nations, 2012). Although difficult to assess rigorously, this vulnerability conceptually begins with drought as purely a precipitation-based measure; the necessary biophysical, infrastructural, social, economic, and political filters are then added to identify those populations for whom low precipitation imposes a serious welfare burden in terms of nutrition, income, assets, and future wellbeing. Given that each of these layers is spatially heterogeneous, the hundreds of millions of vulnerable households tend to be concentrated in specific regions. Drought vulnerability at the national level is highest in Asia and, especially, Africa, although pockets of it exist also in Central and South America (Eriyagama et al., 2009).

p0080 To appreciate the welfare effects of drought among vulnerable households, a few important nuances should be kept in mind. First, although drought often conjures up images of a weatherworn and weary farmer leaning on a hoe and surveying a dusty plot of withering crops that were supposed to produce food for his family, such images can be misleading. Most poor farmers rely heavily on markets for selling their products and even more heavily for *buying* food. This means

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that for many of the rural poor the direct impact of drought on their own food production can be less worrisome than the indirect effect on food prices and households' access to food.

p0085 Second, as mentioned earlier, drought can trigger a series of behavioral responses that imply that the total welfare burden of drought is much higher than what might be observed in the immediate aftermath of a drought event. In addition to the so-called *ex post* risk effect that encompasses these immediate effects, the threat of drought, like a bully, induces households to opt out of higher return livelihoods and store their assets in forms that have low or negative returns but high liquidity. Elbers et al. (2007), using a panel of household data from Zimbabwe to quantify the magnitude of these effects, found that more than half of the drought risk burden is due to this *ex ante* threat of drought rather than its actual occurrence. Similarly, much of the drought burden is essentially hidden from direct observation in many settings.

p0090 Lastly, individual drought coping responses can be aggregated across households in ways that magnify the overall drought burden in a region or country. For example, when livestock markets are poorly integrated, a shared drought event that prompts many to sell animals in order to fund food purchases can cause livestock prices to plummet once local markets aggregate this individual drought response. In an even more dramatic fashion, severe and persistent drought can spur mass migrations of displaced populations and lead to social and political tensions that, when mixed with other instabilities, can create serious conflict. As a case in point, several years of extreme drought in Syria after 2005—which forced many rural households to migrate to urban edges—seem to have set the stage for the subsequent socio-political instability (Hoerling et al., 2011). While extended drought was surely not the only cause of this civil conflict, it acted as a "threat multiplier" that interacted in potent ways with other existing threats (Johnstone and Mazo, 2011).

p0095 Since it is difficult to overstate the burden that drought can impose in some settings, several different angles have emerged to remedy its impacts.[1] Table 22.1 organizes several common drought-related interventions. While this table is intended primarily to provide a backdrop to the discussion of DT and II in the subsequent section, a few things are worth noting. Aside from infrastructure, information, and organizations, many of the interventions treat individuals or households directly, raising some important targeting issues. These issues arise because drought is less of a shared experience than it may seem; idiosyncratic factors (e.g., spatial variation in rainfall, local soil and topographical differences that affect how much moisture is retrained in the soil, differences in cropping and livelihood strategies, and heterogeneous mitigation, coping and recovery capacities) mediate how a particular household bears up in a drought—and how much of an impact a particular intervention might have.

p0100 Many of the interventions in Table 22.1 aim to address *ex post* drought effects directly. Whether or not they also reduce *ex ante* effects depends largely on how reliable they are as perceived by key decision-makers in households before drought occurs. Farmers are unlikely to put their households' welfare on the line based on interventions that may or may not help in the wake of a drought, and drought is likely to continue to impose an important *ex ante* burden. Agronomic technologies and practices may ultimately reduce households' vulnerability to drought, but such households must gain sufficient familiarity and experience with these innovations before they are likely to feel less bullied by the threat of drought.

[1]In an entirely different spirit, drought can bring distinct and important benefits to some interest groups. This can be particularly apparent in political realms where "everybody loves a good drought" (Sainath, 1996). Especially egregious and disturbing are claims that droughts provide opportunities to oppress or punish specific ethnic groups or other factions.

t0010 **Table 22.1 Different Categories of Drought Interventions with Examples for Each**

Type of Drought Intervention	Example
Acute relief	Food aid and humanitarian aid
	Refugee security and support
	Cash transfers and vouchers
Agronomic	Breeding staple crops for better drought resistance and early maturity
	Resource conservation practices such as zero tillage and water harvesting
	Permanent and supplemental irrigation
	Extension to promote adoption of improved inputs and practices
Financial	Income diversification and livelihood support programs
	Microcredit and savings
	Insurance
Organizational	Cooperatives and producer associations to provide access to inputs and higher value markets
	Social organizations to provide informal safety nets
Infrastructural and informational	Improved roads to reduce transport and transactions costs in order to better integrate markets
	Improved weather information and climate models to provide better daily, weekly, and seasonal weather forecasts

s0020 22.3 DT AND DROUGHT II: PROSPECTS AND COMPLEMENTARITY

p0105 The interventions explored in this chapter, DT and II, aim to directly reduce farmers' vulnerability to drought. While both are quite simple conceptually and closely related to familiar approaches to mitigating drought risk, each has evolved rapidly in recent years, thanks to a flurry of investments and innovations in the past decade. This section describes these recent experiences and the near-term prospects for DT and II to reduce drought vulnerability among the rural poor. It also introduces the complementarity between the two, which is the basis for the argument that a bundled DT—II product may be much more potent than each of them in isolation.

s0025 22.3.1 DROUGHT TOLERANCE

p0110 As an agronomic intervention, DT has been a long-standing breeding objective. Conventional breeding has often selected for resistance to moisture or temperature stress in order to target specific agroclimatic zones with improved varieties. What is innovative in the current generation of DT is the set of tools and techniques breeders are bringing to bear on the problem. Agricultural biotechnology tools such as marker-assisted selection have rapidly advanced conventional plant breeding. Genetic engineering likewise pushes the frontier of DT innovation. Although there are dissenting views about how much can be expected from this DT innovation stream (Gurian-Sherman, 2012), the promise and potential of these new breeding tools have attracted almost unprecedented investments aimed at DT research from both the private and public sectors. Major private sector players see substantial profit opportunities for these new generation DT technologies in North America, Australia, and elsewhere in the coming decades. For example, Monsanto estimates that the market for a DT trait in maize in the United States alone could be USD 500 million by 2020 (Monsanto, 2012).

p0115 Monsanto, Syngenta, and Pioneer have all recently released new maize hybrids with new generation DT traits. Monsanto's genetically engineered DT products are marketed as Genuity Droughtgard Hybrids. Syngenta and Pioneer released their (nongenetically engineered) DT maize products in 2012 under the names Agrisure Artesian ("Maximize your yield without risking it all on weather") and Optimum AQUAmax, respectively. Although farmer experiences with these new DT maize hybrids are limited by their recent release, the severe drought conditions prevalent across much of the corn belt of the United States in 2012 provided a useful test of the potential DT benefits they confer. As reported by these seed companies (not peer-reviewed), on-farm trials of these hybrids showed average DT yield benefits in the range of 5−17%. Whereas the DT benefit of the Agrisure Artesian maize hybrids is negligible for environments with average yields above 100 bu/acre (6,250 kg/hectare), the DT benefits for plots with more pronounced drought pressure were more dramatic (48% for plots with yields below 50 bu/acre (3,125 kg/hectare)) (Syngenta, 2012).

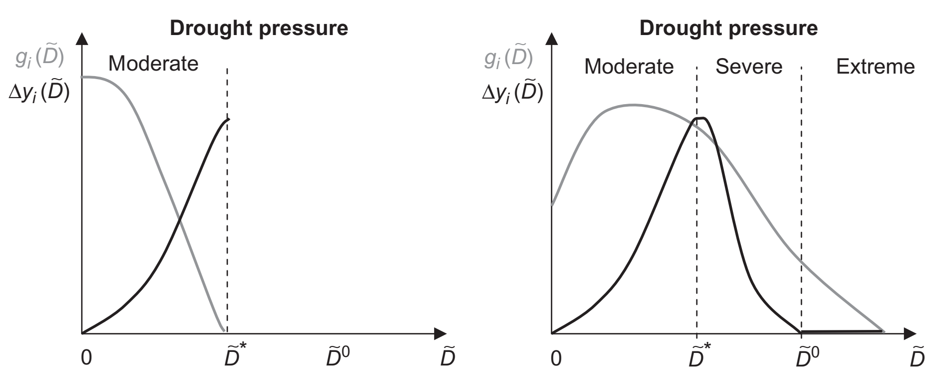
p0120 The private sector's research and development of DT crops since 2000 has been matched by a similar explosion of public sector investments in DT technologies. Universities, national agricultural research institutes, and international research centers of the Consultative Group for International Agricultural Research (CGIAR) have made important breakthroughs in the area, with financial support from development agencies, research foundations, and other donors. Several public−private partnerships focused on DT crops have emerged. Two important such partnerships are focused on breeding DT crops for Africa. One is Drought-Tolerant Maize for Africa (DTMA) project, which was started in 2007 and is coordinated by two CGIAR centers: International Maize and Wheat Improvement Center (CIMMYT) and International Institute of Tropical Agriculture (IITA). It involves several national agricultural research centers, public and private seed companies, and farmer groups in 13 countries. The other is Water Efficient Maize for Africa (WEMA) project, which was begun in 2008 and is led by the African Agricultural Technology Foundation in collaboration with Monsanto, CIMMYT, and several national research centers. Together, these two initiatives have attracted substantial investments in DT research.

p0125 Four features of agricultural research in this area facilitate these public−private partnerships. One, DT research is often characterized by large upfront fixed costs and small (near zero) marginal costs of producing DT traits. Two, agroecological variation implies that breeding these DT traits into maize hybrids that are well adapted to local growing conditions can require significant late-stage breeding effort. Three, private seed companies clearly segment profitable markets for their products from lower priority markets. Four, many private and public agricultural research organizations are eager to demonstrate the potential of agricultural biotechnology in ongoing debates about the costs and benefits of new technologies based on these techniques. Thanks to the confluence of these four features, private seed companies have been eager to collaborate with public research organizations, and the public sector is similarly eager to collaborate with the private companies.

p0130 While it is premature to quantify the impact of the DTMA and WEMA projects on farmers' maize yields in Africa, the growing body of agronomic and field trial results suggests that the hybrids emerging from these public−private initiatives are likely to confer meaningful DT benefits. The WEMA project aims to release its first maize hybrids in 2014 and expects that "increasing yield under moderate drought could mean an additional two million tons of maize during drought years that could feed 14 to 21 million people" (WEMA, 2012). The DTMA project has started releasing some breeding material to national seed systems with the ultimate objective of "generating maize hybrids with a 1 ton per hectare potential under 'drought stress' conditions and increasing the average productivity of maize under smallholder farmers' conditions by 20−30%" (Abdoulaye et al., 2012). Based on many reports of field trials of these improved DT hybrids, the average yields under "managed drought stress" are often in the 1−3 tons/ha range (DTMA, 2014). It is presumably based on such results that the main DTMA website quotes a maize farmer, saying, "This is like crop insurance within the seed."

p0135 In some settings, DT may indeed function like crop insurance, but in others it most assuredly does not—and knowing why not is important to understanding the inherent limitation of DT. Figure 22.1 provides a stylized explanation. Both panels depict the probability distribution function (pdf) of stochastic drought pressure ($\tilde{D}$) as function $g(\tilde{D})$. For now, think of this drought severity measure as a conventional measure like the Palmer drought index with average conditions indicated by zero and increasing positive values indicating increasing drought severity. This figure also depicts the net benefits associated with DT as function $\Delta y(\tilde{D}) = y_{\mathrm{DT}}(\tilde{D}) - y_0(\tilde{D})$. The left panel shows these relationships for a hypothetical location that experiences moderate drought stress, but never severe or extreme drought. In such a location, the farmer on the DTMA website is quite right: DT is like crop insurance built in to the seed. The right panel shows these relationships for a second hypothetical location that experiences drought ranging from moderate to severe to extreme. In such a drought-prone setting, DT is far from insurance-like: precisely when protection is needed most—during severe and extreme drought events—the DT benefits fall as drought worsens, eventually providing no benefit whatsoever. In this setting, smallholders will have a difficult time learning the value of DT, and—seemingly paradoxically—the most risk-averse farmers may be the least eager to adopt DT crops (Lybbert and Bell, 2010). Furthermore, in such a setting, DT crops do little to alleviate the *ex ante* drought burden since households remain under threat of extreme drought.

p0140 With this conceptual model in mind, it is worth returning to the DTMA results. Crops were subjected to "managed drought stress"—that is, crops were "grown during a rain-free period, with irrigation applied at the beginning of the season to establish a good plant stand, then irrigation was



f0010 **FIGURE 22.1**

Stylized differences in drought severity, drought probabilities, and net DT benefits for two hypothetical locations.

withheld so that the crop suffered drought stress during flowering and grain-filling" (Makumbi, 2012). It is not clear whether this treatment simulated drought stress to the right or left of the "optimal drought stress" ($\tilde{D}^*$) at which DT benefits are maximized, but it is quite clear that reduced irrigation at the beginning of the season would quickly erode any DT benefits. While none of the DTMA trials enable one to understand the drought-yield profiles as shown in Figure 22.1, it is almost certainly true that smallholders in Sub-Saharan Africa are more likely to face drought risks like the panel on the right than the one on the left, which has direct implications on the prospects of DT maize in these settings. To underscore this point, consider anew the on-farm trial results reported by Syngenta (Syngenta, 2012).[2] The lowest "yield environment" reported in these results (<50 bu/acre (3,125 kg/hectare)) suggests an impressive 48% yield gain, but a maize yield of this level corresponds to the 90th percentile of maize yields in Ethiopia. It seems likely that the median Ethiopian maize farmer would confront much more modest DT benefits in severe drought.

s0030 22.3.2 INDEX INSURANCE

p0145 Agricultural II works not by insuring the farm household directly against its own specific income or yield losses,[3] but instead by insuring against a direct or predicted measure of the average or typical losses experienced by farms located in the vicinity of the household. An II contract can be represented as an indemnity schedule that links payments to an index that predicts typical losses in the zone covered by the index. To avoid problems of moral hazard and adverse selection, the level of the index cannot be influenced by the actions of the insured, nor can its level depend on which particular individuals choose to purchase the insurance.

p0150 Recent technological advances in remote sensing and automated weather measurement that permit estimation of crop losses (as well as the potential of older ideas like area yield insurance[4]) have opened the door to innovative II contracts. Realizing the risk transfer potential of these advances faces both demand- and supply-side constraints, although a number of recent projects had shown that the supply-side challenges can be overcome.

p0155 Despite this supply-side progress, contract demand and uptake have been sometimes tepid. As discussed in Carter (2012), a number of demand-side challenges remain, including devising insurance indexes that are highly correlated with individual farmer outcomes (reducing residual uninsured or "basis" risk). An emerging but still small body of research shows that when these problems are resolved, the impacts of II can be substantial (Elabed et al., 2013; Janzen and Carter, 2013; Karlan et al., 2012).

p0160 Even as II for small farm agriculture is still a work in progress, this chapter focuses on its complementarities with DT varieties. That is, II can insure extreme event losses where even DT varieties fail, whereas DT is a more cost-effective risk management tool than II for less extreme events. As a

[2]In an entirely different spirit, drought can bring distinct and important benefits to some interest groups. This can be particularly apparent in political realms where "everybody loves a good drought" (Sainath, 1996). Especially egregious and disturbing are claims that droughts provide opportunities to oppress or punish specific ethnic groups or other factions.

[3]Myriads of experiences show that trying to insure all sources of variation in agricultural outcomes for small farmers is beset by a host of problems rooted in the costs of obtaining information on small farm outcomes that renders such insurance infeasible (Hazell, 1992).

[4]Area yield insurance measures average yields in a defined geographic area (e.g., a valley or administrative district) and makes payments when these average yields fall below a specified "strike point" level.

package, they thus offer a relatively low cost but highly effective risk management solution. Demand for such a bundle is likely to be high,[5] creating a sustainable market for both products.

p0165 Prior to discussing the analysis that substantiates these points, it is worth mentioning one key difference between DT varieties and II. The development of DT varieties has extremely high fixed, upfront costs, but once the varieties are developed the marginal costs of offering the DT trait to farmers is close to zero. On the other hand, II has modest upfront development costs, but it requires the payment of an annual premium, which is composed of the expected payout plus an additional loading required to cover distribution and other administrative costs. While governments and donors appear willing to subsidize the upfront development costs for both DT varieties and II, they are seem less willing to subsidize an annual premium. For this reason, in the analysis to follow, the DT seeds are assumed to cost the farmer no more than non-DT seeds, and that the farmer must pay the full annual cost of the insurance premium.

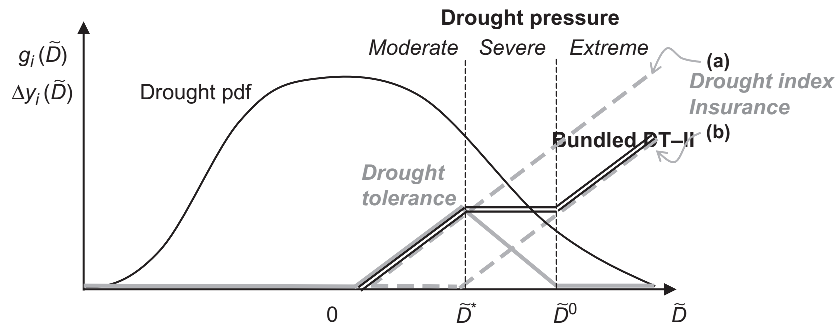
p0170 This feature of the cost structure of the II industry provides a central motivation for bundling DT and II. Specifically, it implies that farmers' willingness to pay for these insurance products will critically determine the viability of these financial markets. In other words, poor farmers will only have access to an appropriate selection of II products if their demand for these products is sufficient to sustain and encourage the development of these markets. In some contexts, this reality may be at odds with existing evidence suggesting that farmers can be quite sensitive to price when facing II products.

s0035 22.3.3 THE DT−DROUGHT II COMPLEMENTARITY

p0175 Given the specific limitations of stand-alone DT and II, this section tackles the complementarity that makes bundling them potentially interesting. This complementarity, which is tied to drought severity, is quite simple. A bundled DT−II product can offer monotonic benefits as drought severity increases because II can incrementally cover the severe drought pressure beyond the point where relative DT benefits begin to fade. On the flip side, with DT covering low to moderate drought events, II can be designed so it only covers more rare and extreme droughts, which can substantially reduce the actuarially fair premium associated with the insurance. In this way, bundling II with DT may offer what governments and donors seem unwilling to provide: a long-term—albeit implicit—subsidy on II premiums.

p0180 Figure 22.2, which borrows the format and notation in Figure 22.1, graphically depicts the essence of this complementarity. The net yield gains associated with DT are represented as a triangular distribution centered on $\tilde{D}^*$. As before, these net DT gains begin to decrease in severe drought and are zero in extreme drought when crops fail (i.e., when yield is too meager to justify harvesting). Two II contracts are depicted in Figure 22.2: (a) a "full coverage" contract that pays out in moderate, severe, and extreme drought and (b) a potentially much cheaper "limited coverage" contract that pays out only in severe and extreme drought. Finally, the figure shows what a stylized DT−II bundle would look like in this case. Note that as drought intensity increases in the severe drought range the falling DT net gains are offset by rising II payoffs. In extreme drought, II continues to provide a payout. In this stylized example, the resulting payoff profile for bundled DT−II

[5] Work by Karlan et al. (2012) and McIntosh et al. (2013) shows that the demand for index insurance appears to be quite price elastic.



f0015 **FIGURE 22.2**

Stylized depiction of the complementarity between DT and II with two drought II contracts depicted: (a) high coverage, relatively expensive II and (b) low coverage, cheaper II designed to be bundled with DT.

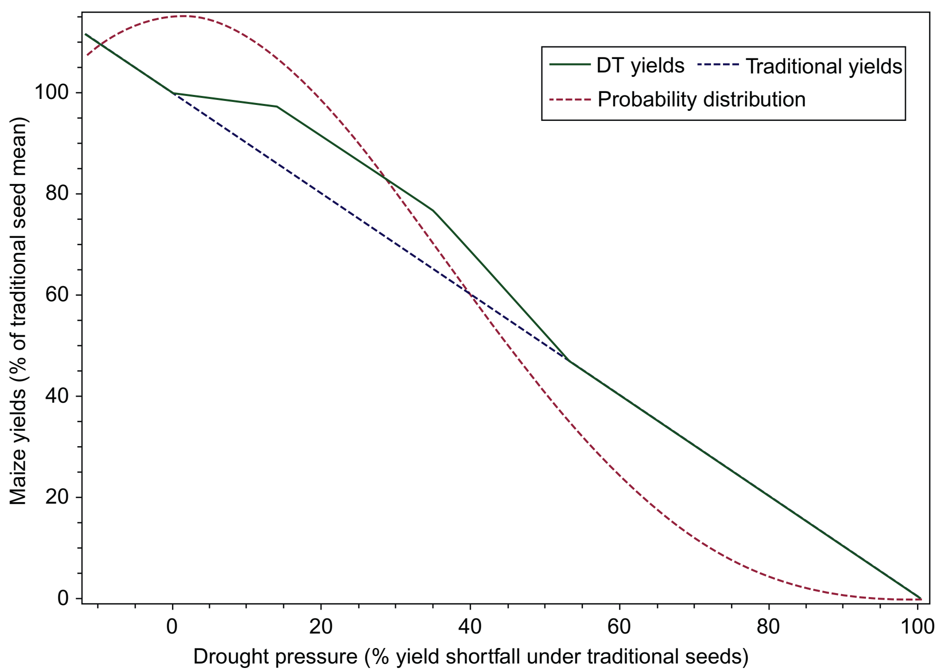
is never decreasing in drought severity, which implies that such a bundled product can reduce both the *ex post* and *ex ante* drought risk burdens.

p0185 In practice, bundling a particular DT crop with II raises a few important—if somewhat nuanced—considerations. First, whereas the net payoff profile for a DT crop can only be altered through hard-earned breeding breakthroughs and innovations in agronomic practices or other inputs, the payoff profile for II can easily be changed to fit a given context. Before one can properly construct an II contract that complements a given DT crop, one must understand the net yield profile of the DT crop. Second, although the depiction in Figure 22.2 suggests that modifying the II contract to complement the DT crop is simply a matter of changing the strike point (i.e., the point along the drought index continuum where the contract begins to payout), in practice optimizing the design of an II contract to fit a particular DT crop is likely to be more complex than this. To the extent that a DT trait changes the relationship between drought and yield at different levels of drought severity, optimizing the bundled II contract may require more than adjusting the strike point.

s0040 22.4 CALIBRATING AND EVALUATING A DT–II BUNDLE FOR MAIZE IN ECUADOR

p0190 This section presents an analysis of how a DT–II bundle might operate in practice using maize data from a drought-prone region of Ecuador. The Ecuadoran government annually collects yield data from random samples of producers in different regions of the country (Castillo et al., 2012).[6] This analysis used maize yield data covering 2001–2011 from the coastal Guayquil department to estimate the underlying probability structure for the traditional maize yields. In Figure 22.3, the below average yields were standardized by the long-term average yields in the region (i.e., the mode of the probability distribution is at 100%). While factors other than drought stress explain some of the yield

[6]Data came from the annual ESPAC survey collected by the Ministry of Agriculture. More details on the survey can be found in Castillo et al. (2012).



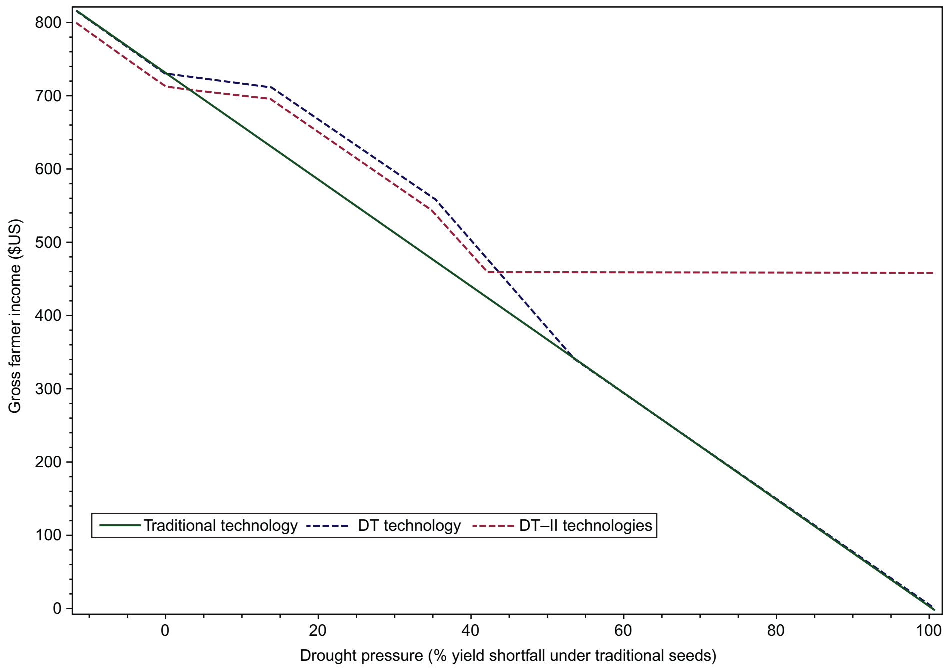
f0020 **FIGURE 22.3**

Probability distribution of drought pressure in Ecuador (measured as yield shortfall from average yield of traditional maize) and the stylized, hypothetical yield advantage of DT maize.

variability, for simplicity all yield declines were assumed to be driven by drought stress, and shortfalls from average yield were used as a proxy for drought pressure on the horizontal axis.

p0195 Based on the limited evidence described above, some stylized assumptions were made about DT impacts. The dashed 45° line in Figure 22.3 graphs the yield shortfall under the traditional technology as a function of itself as a benchmark, and the solid line displays the assumptions about DT yields. The assumptions are as follows:

- u0015 For moderate drought pressure, DT stabilizes yields at nearly their long-term expected average even as yields under the traditional technology fall up to 15% short of that average (there is a 15% probability that yields will fall in this range).
- u0020 As drought pressure increases, and traditional yield shortfall increases from 15% to 35% of the long-term average, DT yields also begin to slowly decline.
- u0025 DT maintains a 20% yield advantage, compared with non-DT seeds, over this range (there is a 20% probability that drought pressure and yields will fall in this range).
- u0030 As drought pressure further increases the yield shortfall to 55% of the long-term average (a 10% probability), the advantages of DT disappear and DT yields become identical to traditional yields over the lowest 5% tail of the probability distribution.



f0025 **FIGURE 22.4**

Performance of DT and bundled DT—II products measured in gross farmer income as a function of drought pressure in Ecuador.

p0220 In summary, the assumption is that DT affords modest to strong yield advantages 90% of the time under unfavorable conditions.

p0225 Further, two stylized II contracts were considered. The first has a strike point of when the yield shortfall reaches 15% of the long-term average. Under this contract, farmers are compensated dollar-for-dollar for every loss in area yield that occurs beyond this point. Under this high coverage contract, farmers would never receive less than the value of 85% of their long-term mean yield, less the cost of the premium. The other contract considers a lower strike point and has a low coverage; it begins to pay off when the yield shortfall hits 35% of the average, stabilizing farm incomes at levels that would be realized under these conditions. This lower coverage strike point coincides with the point where drought pressure begins to overpower DT and DT benefits begin to fade.

p0230 Figure 22.4 compares these alternative agronomic and financial technologies. Using the current market value of maize in Ecuador, the traditional maize returns an average gross income of USD 716 per acre (1,790 per hectare), whereas DT varieties under the study's assumptions would return USD 750 (1,875 per hectare).[7] While this is a modest increase, DT also has a substantial impact on risk. Figure 22.4 illustrates gross incomes under traditional (green solid line) and DT technologies AU:2

[7]The proportionate increase in net income would, of course, be much larger, assuming that the cost structures of DT and traditional production are identical.

t0015 **Table 22.2 Consumption and Certainty Equivalent Performance of DT, II, and Bundled DT−II** AU:7

	Additional Cost Above Traditional Technology (USD/acre)	Mean Gross Income, USD (Net of Insurance Costs)	Certainty Equivalent, USD/acre	% Change in CE
Traditional maize	–	716	675	
DT maize	–	750	715	6.1
II-high coverage (15% yield shortfall strike)	66	710	692	2.6
II-low coverage (35% yield shortfall strike)	20	718	688	1.9
Bundled DT−II with low coverage II "optimized" for DT yield distribution	13	748	723	7.2

(blue dashed line) as a function of drought pressure. To value this change in risk, the certainty equivalent of the gross income streams implied by the two technologies was calculated, assuming that individuals' preferences can be characterized by a constant relative risk aversion utility function, with a coefficient of relative risk aversion of 1.1. As Table 22.2 shows, the certainty equivalent of the DT technology is 6.1% higher than that of the traditional technology (USD 715 vs. 675 per acre (USD 1,787 vs. USD 1,687 per hectare)).

p0235 Table 22.2 also reports the certainty equivalent value of stand-alone II that is introduced to farmers using traditional technology. The high coverage contract would cost USD 66 per acre (USD 165 per hectare) and modestly reduces expected gross income because the insurance is priced at 20% above the actuarially fair price. However, even with this markup, this insurance would increase the certainty equivalence by almost 3%. The low coverage contract, when introduced with traditional technology, costs USD 20 per acre (50 per hectare) and increases certainty equivalence by about 2%.

p0240 As the comparison of the two II contracts makes clear, farmers would clearly value the additional stabilization of yields provided by the higher strike point contract. However, can this additional stabilization be provided more efficiently by DT seeds rather than by a high strike point insurance contract? Similarly, the certainty equivalence of DT technology is reduced by the fact that the technology fails under extreme conditions. Can the additional stabilization provided by a low strike point contract offer substantial additional value to the risk-averse farmer?

p0245 The final row in Table 22.2 addresses these questions. The analysis assumed that the low strike contract is calibrated to DT yields. That is, the contract only begins to pay off when the DT (not traditional) yield shortfall is 35% of the long-term average of traditional seeds. Since these lower yields are less likely with DT seeds, the cost of this insurance falls from USD 20 to 13 per acre (USD 50 to 32.50 per hectare).[8] In combination, the DT−II bundle yields a gross income function given by the dotted red line (Figure 22.4). The bundle stabilizes gross farmer income levels under the most extreme conditions. It also reaps the benefits of DT under moderate drought pressure.

[8]This insurance price would further incentivize the adoption of DT varieties.

As reported in Table 22.2, the certainty equivalent of the DT−II bundle is USD 723, or 7.2%, higher than the certainty equivalent returns of the traditional technology. While it is doubtlessly possible to design more finely tuned packages, this simple example does illustrate the complementarity between DT and II technologies, based on their complementary statistical properties.

s0045 22.5 CONCLUSION

p0250 Many of the world's poor are vulnerable to drought in some way. Climate change adds urgency to alleviating their drought vulnerability, which imposes a serious welfare burden on the poor. While DT and II have attracted substantial attention as stand-alone interventions, this chapter argues that their true potency is likely to emerge only when they are properly bundled. Such bundling overcomes their stand-alone limitations by leveraging a fundamental complementarity between the two. This complementarity was demonstrated conceptually using maize data from Ecuador; the analysis illustrated how a bundled product could look and how it might affect household welfare.

p0255 The argument for bundling DT and II rests firmly on its prospective benefits to farm households. This perspective (i.e., benefits to farming households) must remain central to any effort to calibrate and refine a DT−II product in practice. How should an II contract be optimized to properly reflect a given DT benefit profile? What information will farmers need about these DT-optimized contracts to appreciate the synergies associated with bundled DT−II? In this analysis, the case for bundled DT−II was found compelling in contexts where the risk of extreme drought and total crop loss is nontrivial, although several key design and delivery questions remain. With the expected release of many DT crops in the near future, now is the time to begin exploring these questions.

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NON-PRINT ITEM

Abstract

With projections of more severe and more frequent extreme weather, farmers' vulnerability to weather shocks such as drought will remain central to global poverty concerns and policy debates for decades. Drought-tolerant crop varieties have attracted widespread attention. Index insurance has garnered similar enthusiasm. In many settings, neither drought tolerance nor index insurance in isolation will be sufficient; the full potential of either might be tapped only when bundled with the other. Drought-tolerant crops may protect against moderate drought only, leaving farmers exposed to extreme drought. Drought index insurance can provide a more complete protection, but farmers may be unwilling to pay its premium. Proper bundling of the two innovations may help resolve this conundrum by leveraging complementarities between them. This study calibrated such a bundled drought tolerance–drought index insurance package in the context of Ecuador to illustrate the possibility.

Keywords: Drought; vulnerability; drought tolerance; index insurance; risk