Chapter 5: TECHNICAL FEASIBILITY: CREATION OF THE BLACK BOX

Having successfully completed the prefeasibility stage and made the decision to progress with a WII approach, the next step is to actually create the index—the "black box" and the prototype insurance contract. Given the novelty and technical complexities of designing weather-indexed contracts for agriculture, it is strongly advised that professional experts in agro-meteorology and agricultural insurance are hired to assist a project team. The experts will assess the various insurance options, create the black box, and subsequently adjust the contract parameters to best reflect the desired protection that will meet the stated project objective.

This chapter will not seek to explain in detail the technical steps that need to be taken by the experts, but rather illustrate what they will be doing, what answers they will be looking for, and what general challenges they will face. This illustration is provided for the target audience of this discussion paper: task managers, donors, and various other forms of WII promoters. Specific details on the technicalities and a modular-based training tool can be found at http://www.agrisktraining.org. This training tool is aimed at insurance industry professionals, academics familiar with the modeling systems, and generalists who already have a relatively in-depth knowledge of WII.

At the outset it should be noted that various methodologies can be used for designing WII contracts. In addition, and as in the prefeasibility stage, the technical feasibility also requires the application of "art" and science. The science is required for building a mathematical model that will serve as a proxy for losses. The art is the application of technical knowledge and qualitative information obtained from farmers and experts to adapt the model so that it responds to the specific context (thereby addressing or minimizing basis risk). As there is no unique way to conduct this process, this chapter is merely illustrative of the major steps required to develop the prototype contract.

In essence, the first step will be undertaking three pieces of interrelated analysis:

- Exposure assessment
- Hazard (or risk) assessment
- Vulnerability assessment

The output of these analyses will be:

- The mathematical probability of an occurrence of a given weather risk
- The potential intensity of that weather risk
- The potential level of damages caused given the intensities assessed

Depending on the model used and the professionals who are engaged, these pieces can be explicit or implicit in their step-by-step activities to design an index insurance contract. The descriptions of these interrelated activities in this chapter are shown more for illustrative purposes and do not necessarily reflect a particular process of designing contracts. A detailed technical explanation and process of developing index weather insurance, as ARMT has mainly done in piloting projects, can be found in Annex 6.

It is thus important for task team leaders (TTLs) to know that there is no one single way to design an index, and that indexes can vary significantly. An appropriate index for a client will predict loss events and their magnitude with a sufficient level of accuracy. In some cases simple indexes such as the amount of total cumulative rainfall in a season will be appropriate, while in other cases much more complicated indexes such as dynamic crop models will be appropriate. In all cases once a robust index that accurately captures the losses faced by clients is determined, one can go on to design and structure an appropriate index-based weather insurance contract or simply analyze the weather exposure of a client, thereby guiding investment decisions, business plans, and actions for various entities exposed to weather risk.

These three pieces of information will provide the basic quantitative elements for designing an index and structuring and pricing a WII contract.

FIGURE 5.1: Example of Rice Crop Cycles

	June (1 2 3 4)	July (1 2 3 4)	Aug (1 2 3 4)	Sep (1 2 3 4)	Oct (1 2 3 4)	Nov (1 2 3 4)	Dec (1 2 3 4)
Rice crop cycle 1		Seeding	Tillering	Booting	Flowering, Grain Filling		Harvest
Rice crop cycle 2	Seeding	Transplant	Tillering	Booting	Flowering, Grain Filling		Harvest
Rice crop cycle 3	Seeding		Tillering	Booting	Flowering, Grain Filling	Harvest	
Rice crop cycle 4	Seeding	Tillering		Booting	Flowering, Grain Filling	Harvest	
	21 days, 5 days	49–70 days		14 days	14 days, 21 days	depends on available machines and labors	
Average rice growth stage	Seeding	Transplant	Tillering	Growing / Booting	Flowering	Grain Filling	Harvest
Average rice height (cm)	0–25	25–50	50–70	50–70 / 70–110	110–160	160	160
Critical water depth (cm)	25	25	40	70 / 20	160	160	160
Critical flooding time (days)	>3	>3	>4	>4	>4	>4	>4

Source: ASDECON 2008.

5.1 EXPOSURE ASSESSMENT: HOW THE CROP BEHAVES

The objective of this work is to quantify potential yield losses that are associated with particular weather risks at various stages of the crop cycle. Although this exposure analysis uses the same principles as that used for property insurance, in agriculture there is an additional need to understand how a crop behaves in response to changes in weather variables at different stages of plant development. In essence, a building will react to a weather variable in the same manner throughout a given period. A plant, on the other hand, will react differently depending on what stage of growth it has reached. The experts will need to quantify potential losses or reductions in yields at various phases of the crop cycle. Therefore, an agronomist who knows the phenology of the identified crop, and who can divide the crop production cycle into various phases, will be needed during this stage of the assessment.

Figure 5.1 provides an example of rice crop cycles from seeding in June until harvest in December in a rice-producing district in Thailand. This is the initial information that will serve as the basis not just for identifying the various risk phases, but more importantly for identifying the critical periods for any given level of weather hazards. This information is also useful for estimating the increasing accumulated production costs where the insured amount is defined in terms of production costs.

Figure 5.2 shows a maize crop cycle from planting in April until harvest in November, with the identification of critical periods of rainfall at various phases in a particular location.

Information on crop phases and identification of critical water needs during the crop cycle enable experts to design a rainfall index that differentiates between timing of rainfall, as opposed to merely being based on accumulated rainfall. This differentiation is captured in the model through weighting of rainfall. Most WII experts divide crop cycles into periods of 10 days (*dekadal*) to capture the water needs of a crop at close intervals and allow for this weighting. Additionally, a number of other variables are used in the crop models that lie behind an index (for example, soil type, evapotranspiration rates, and temperature), which improves the ability of the model to mirror the actual behavior of the plant. Crop models, in many cases, can be used as the underlying index. Crop models can be simple water-balanced crop models, such as the Water Requirement Satisfaction Index (WRSI) originally designed by the Food and Agriculture Organization (FAO).[13]

Putting the technicalities aside for a moment, the important things to note at this stage are that the exposure assessment is seeking to:

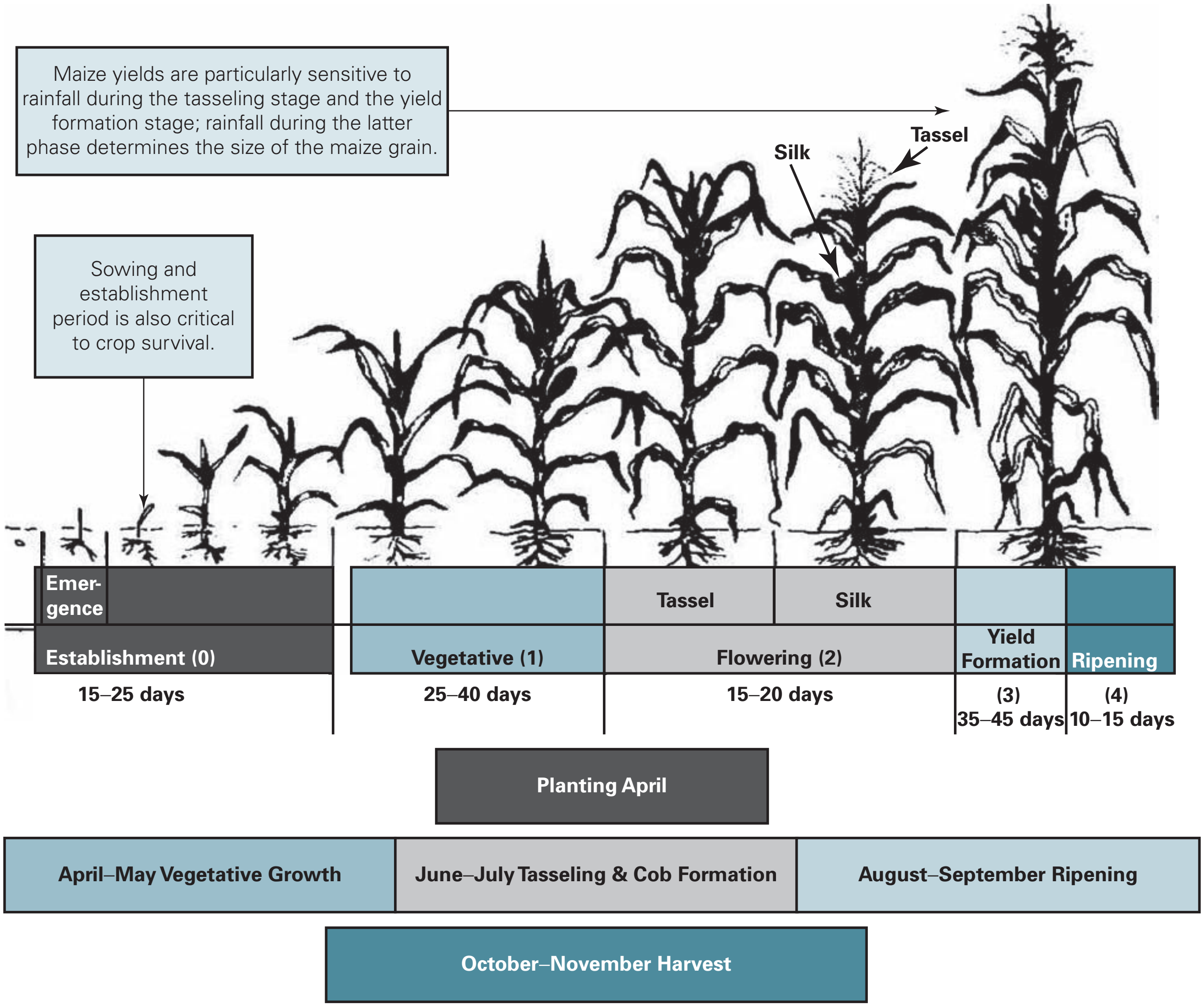
- More precisely identify the critical weather risks at various stages of the crop cycle
- Quantify the value of exposure to weather risks at different phases during cycle
- Provide information for assigning weights to given weather risks
- Quantify the farmer's weather exposure per unit of the defined index
- Quantify the yield volume lost per unit index

In order to achieve this, the experts are seeking answers to the following questions:

- What weather risks are critical in causing yield variability?

13 For a more detailed technical explanation of WRSI, see Annex 7.

FIGURE 5.2: Example of Maize Farmer Cropping Calendar



Source: FAO.

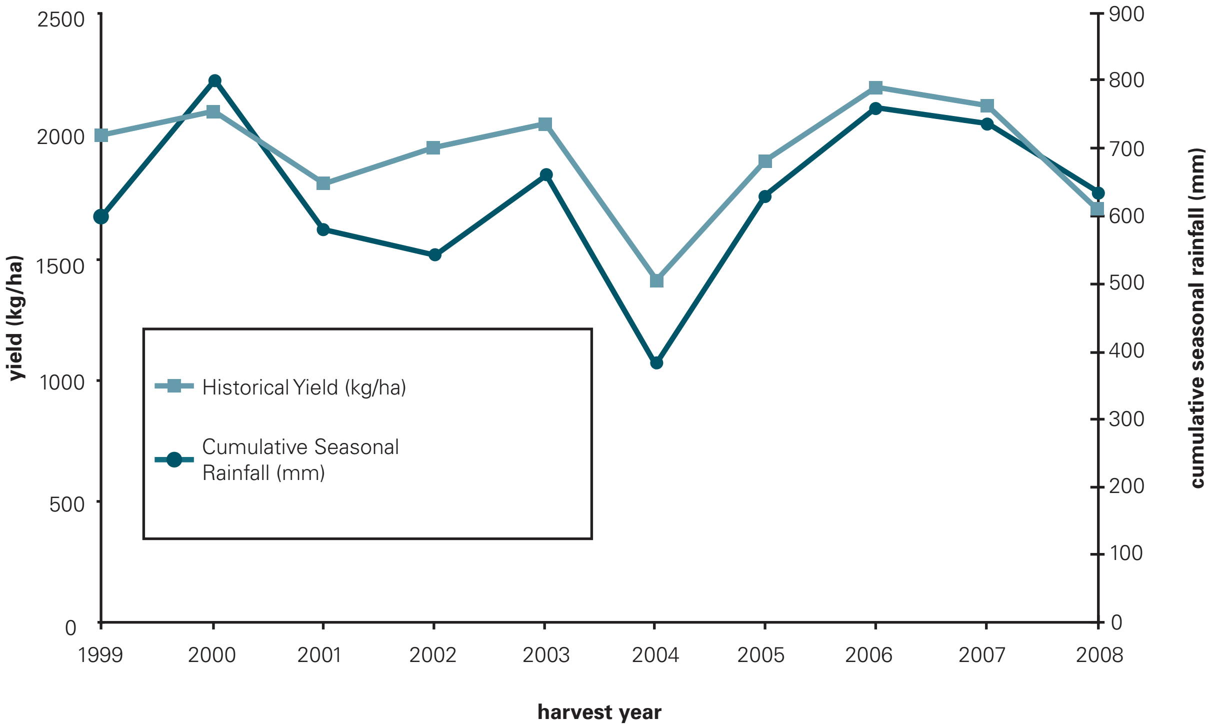
- Which are the critical periods for the crop in terms of weather risks?
- Is there sufficient scientific research on the crop cycle and resilience of the crop to weather risks to be able to design an index that can proxy with sufficient accuracy?
- What is the right weight to assign to critical and non-critical phases for the index?
- What are the exposed values at various phases of the crop cycle?
- Does the proposed index capture the risk in question?

5.2 CORRELATION OF THE INDEX WITH "REALITY"

The final decision as to the acceptability of the crop model and the derived index will obviously lie with the task manager or developer of the WII initiative. While the experts will be hired to provide their input, they will not be taking responsibility for the final product. This is a challenging situation, as most task managers will not have sufficient technical knowledge to enable them to assess the accuracy of the index. However, for assessment of the index's performance in terms of assessing yield, the simple method to test this is to ask the specialists to compare the index with actual, historical crop yield data. The degree to which they match or correlate will demonstrate how efficient the index is at providing a proxy for yield. An example of this correlation exercise is shown in figure 5.3.

As can be seen, the index in this situation does appear to provide a relatively close correlation between the index and the actual yields. If the correlations in an exercise of this kind do not come up very strong, then the first option may be

FIGURE 5.3: Alaba Wereda Maize Yields Versus Farmer's Maize Rainfall Index



Source: Authors.

to revisit the proposed weightings in the index to assess whether they need to be adjusted. While this may increase the correlation, care needs to be taken to avoid a phenomenon known as "overfitting." This occurs when an index is weighted in a certain way and variables are then constructed to ensure a high level of correlation. Unfortunately, while this approach may be used to adapt to historical data, it may result in the index performing in a manner that does not serve as a useful proxy in the future. In simple terms, while mathematical "fitting" can be used to achieve correlations, unless there is a clear understanding that the cause of the lack of correlation is mathematical and not some other physical variable, then mathematical fitting may well not capture further physical variables in the future.

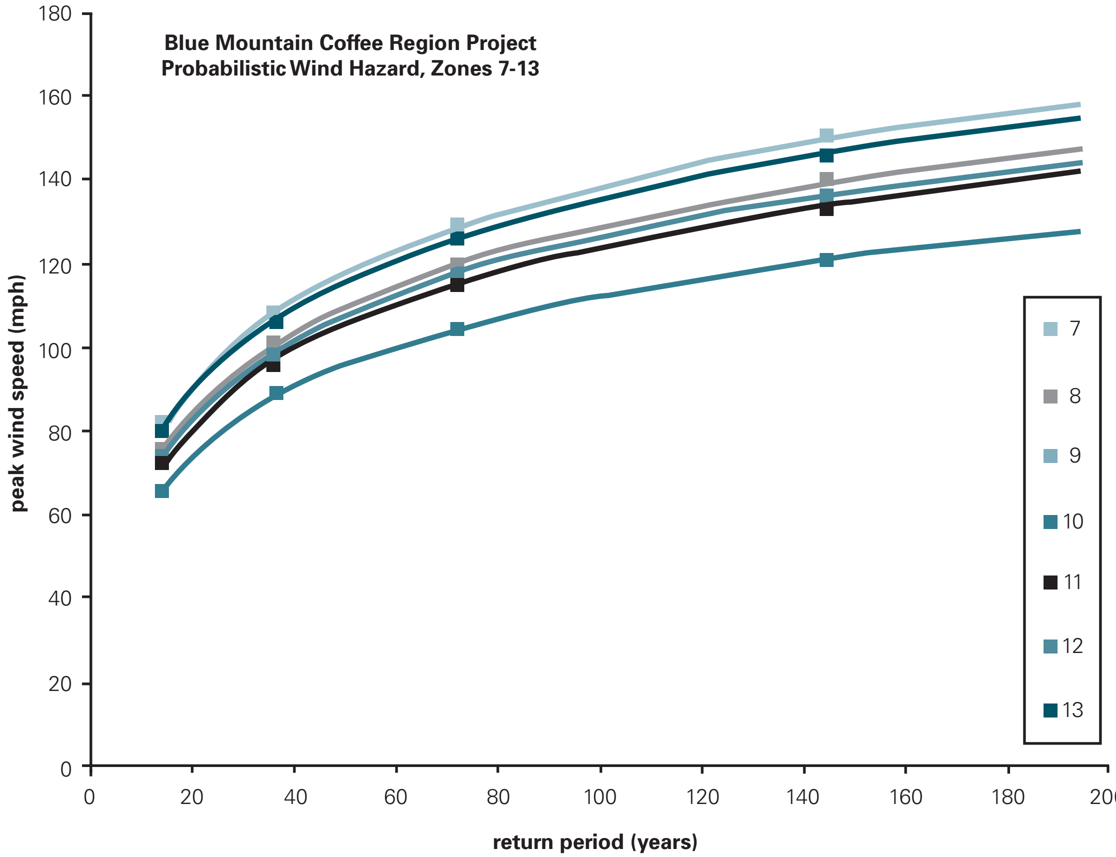
5.2.1 Farmer and Local Expert Interviews

A complementary approach to selecting a weather index is to utilize farmer or local expert recollections of difficult years. It is particularly valuable if these actors can recall the growing seasons when the crop faced particular difficulties in a certain year due to weather or some other risk. Such interviews can also be very useful for verifying other sources of data, such as historical yield data, and understanding the underlying causes for and ramifications of the variations in such composite data sources. As with the historic yields data, this information is likely to be noisy, and it can be difficult to discern the impact of specific events. However, it also provides important information that could distinguish a robustly performing index from one that is inappropriately designed. In some cases, this may be the only information one may have to identify an appropriate index.

5.3 HAZARD ASSESSMENT: HOW WEATHER BEHAVES

The objective of this work is to generate models of expected hazard frequencies for weather variables (such as rainfall, temperature, and wind speed). These weather models also need to be designed with enough spatial resolution to enable them to capture field level variations. In simple terms, the experts will be trying to construct the whole range of probabilities, based on historical weather data sets, for various intensities or magnitudes of weather events. This is known by insurers as the "return period" (for example, wind speeds of 90 miles/hour will hit the pilot area once every 40 years). The outputs from this modeling are called exceedance frequency curves. In figure 5.4 we have given an example taken from simulations done in Jamaica, showing the probabilistic wind hazard exceedance frequency curves for seven zones in the Blue Mountain area.

FIGURE 5.4: Example of Wind Hazard Exceedance Curves



Source: Carib RM 2010.

Given the highly technical nature of this modeling work, it is advisable to have the historical probabilistic models generated by the experts peer reviewed by an independent party (with similar technical expertise). The TTL will find that this hazard analysis is at times implicit in a mathematical model or spreadsheet calculations for WII contracts, and it is not so obvious that this analysis is being done at varying levels of rigor. It is, however, mentioned here to illustrate this technical component of contract design. Underwriters in insurance and reinsurance companies rely heavily on this information in the process of pricing a contract.

During the hazard assessment, the experts will be seeking to answer the following questions:

- Is there sufficient historical, quality weather data to model the curves?
- Is the data of sufficient spatial resolution to capture identified risks in the pilot zones?
- What is the level of confidence that basis risk under the curve has been minimized?
- Do the hazard curves accurately represent the return periods perceived by farmers?

5.4 VULNERABILITY ASSESSMENT: HOW BIG MIGHT THE LOSSES BE—AND FOR WHOM?

This assessment aims to quantify the immediate fiscal impact of the weather risk on farmers. The outcome of the assessment assists definition of the main contract parameters (for example, insured amount, risk retention levels, and the triggers per phase for the insurance contract). This exercise will provide the contract designer with the elements to tailor the insurance contract to the risk profile and needs of the beneficiaries. Box 5.1 provides a summary of illustrative steps that are usually taken when conducting a vulnerability assessment.

Both qualitative and quantitative analysis of risk perception should be conducted through interviews, secondary literature reviews, focus groups, surveys or questionnaires, and discussions with stakeholders and experts.

BOX 5.1: Basic Questions to Answer in a Vulnerability Assessment

1. **Identification of vulnerable groups.** A vulnerability profile should be generated to understand a group's exposures to both spatial and temporal risks. This is to identify a group's main characteristics within the homogenous zone.
   a) How many groups, districts, and farmers are vulnerable? How are these groups affected by risks?
   b) Which are the most vulnerable households? (for example, small landholding, highland areas, nondiversified income individuals)
   c) Who are the most vulnerable individuals?
   d) Are groups affected (quantitatively) differently? Why?
   e) What is the production average over the last 10 years?
   f) What are the factors most highly associated with groups' vulnerabilities?
   g) When do they face these hazards?
   h) What is the seasonality of income activity?
2. **Cataloging assets in a system.**
   a) How have groups' income levels been affected by weather events?
   b) What is the crop planted area for each weather homogenous zone?
   c) What is the average production harvested per month/season?
   d) What is the farm gate price received?
3. **Mitigating or eliminating the most serious vulnerabilities.**
   a) After a disaster, do farmers have access to financial services that contribute in minimizing vulnerability?
   b) Which coping strategies could be identified?

Source: Authors.

The outputs of a vulnerability assessment normally include:

- A description and analysis of present vulnerability, including representative vulnerable groups (for example, specific livelihoods at risk by weather hazard)
- Vulnerability indicators, including impact on investment, income, debt, employment, and export earnings due to weather risks
- Vulnerability maps and profiles for districts, groups, and growing production areas
- Comparison of groups' vulnerabilities under different types of risks and location
- Potential crop production losses for different weather events

5.5 STRUCTURING THE CONTRACT

Based on the qualitative and quantitative outputs generated in each of the three assessments mentioned above (exposure, hazard, and vulnerability), an agricultural insurance specialist should be in a position to structure an insurance contract. Basically, three main issues need to be resolved in the process of contract structuring:

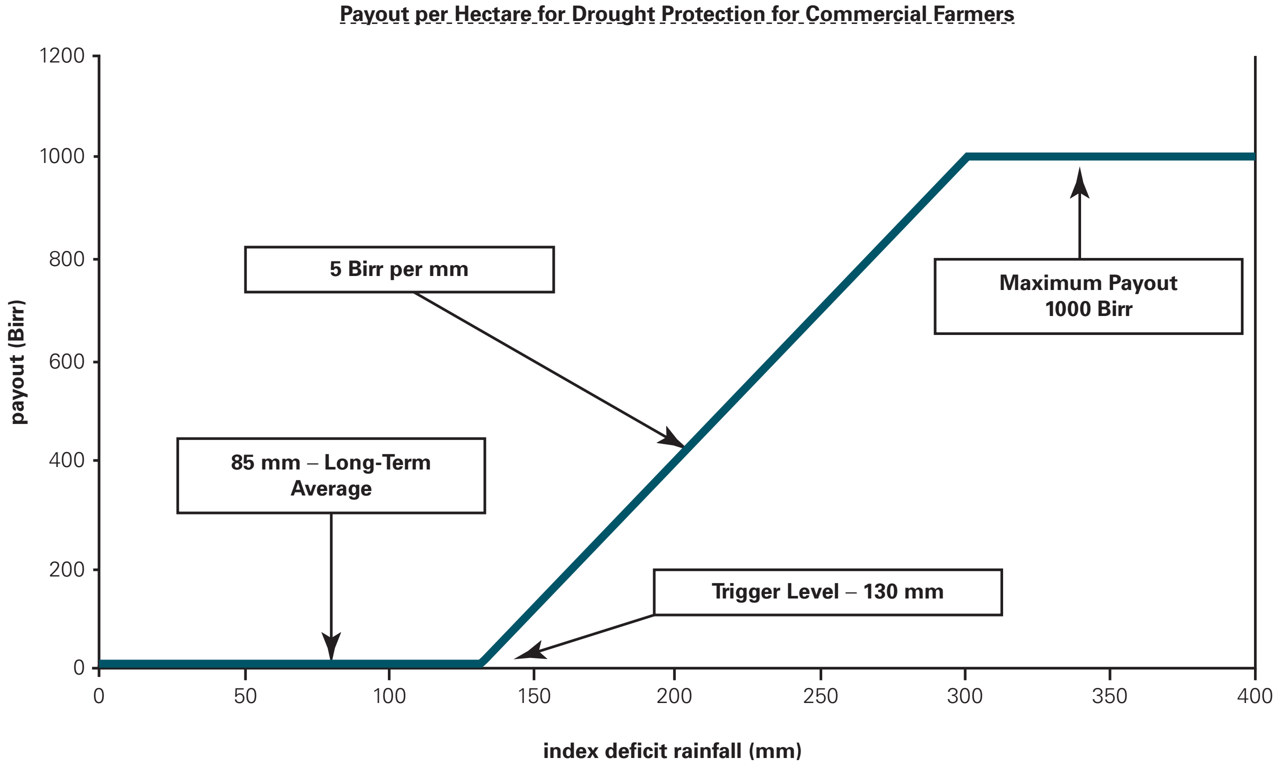
- **Trigger payout levels.** In a traditional contract, the insurer will price the contract based mainly on probabilistic models, and payouts will be made in accordance to an ex-post loss assessment. For index-based contracts, however, it is necessary to agree to an ex-ante payout scale that will determine how much the contract will pay for each unit of weather variable. This scale is measured in ticks and is expressed in terms of intensity of the event (for example, millimeters of rainfall, degrees of temperature, miles per hour of wind speed, and so on).
- **Pricing of the contract premium.**
- **Ensuring that the payout level is sufficient.** The prototype contract must be carefully reviewed to ensure that it offers the level of protection required by the insured, depending on the project objective.

The contract selected must perform an insurance function for the buyer (that is, the index must capture the risk in question and perform well from an agro-meteorological point of view), thereby satisfying both client and regulatory requirements. The specific details, values, and combinations of these features (and the resulting contract) depend on the risk profile and demands of the clients, and the context in which the insurance contract is being introduced to manage weather risk.

In order to address these issues, the specialists will be seeking to answer the following list of questions:

- Does the contract capture local conditions and environment as well as crop specific agro-meteorological risk?
- Does the contract adequately cover the major identified risks?
- Is the risk retention fixed in the contract acceptable to farmers?
- How often and how much will the prototype contract be paying out?
- Do various levels of payouts respond to farmers preferences?

FIGURE 5.5: Contract Parameters in an Indexed Drought Contract



Source: Authors.

- What is the cost-benefit of such a contract versus other alternatives to manage risks (for example, irrigation)?
- Will farmers be paying too much premium for too little coverage?
- Does the prototype contract meet the project stated objective?

Figure 5.5 shows a simple illustration of the results obtained while structuring an index contract for a project in Ethiopia. This simple graphic can be very useful for a project team to share the results of the exercise with various stakeholders.

This hypothetical contract will start paying when there is a rainfall deficit of 130 mm and will continue paying 5 Birr per each millimeter of rainfall deficit until accumulating the total payout in the contract of 300 mm of rainfall deficit for a maximum payout of 1000 Birr. Any yield losses due to rainfall deficit below 130 mm will be assumed by the farmer.[14]

14 ARMT has developed a contract optimization tool that can be very useful for changing initial contract parameters to optimize farmers' coverage. This can be found in the WII training module at http://www.agrisktraining.org.

Another illustration of a simple payout structure for flood damage (from a World Bank study done for index flood insurance) is shown in table 5.1. The advantage of presenting the contract parameters in a table format like this is that it is easier for nonspecialists to understand and explain to farmers. In the end, what farmers want to know is how much their payout will be based on certain levels of either weather excess or deficit. In the example in the table, there are agreed percentages of production costs the contract will pay out for four given levels of inundation over 60 cm of flood.

TABLE 5.1: Flood Index Insurance Structure with Total Production Costs as Sum Insured

DAYS OF INUNDATION OF 60 cm FLOOD	YIELD DAMAGE	INSURANCE PAYOUT
3 days	No damage	No payout
4 days	20% loss	20% of total production cost
5 days	60% loss	60% of total production cost
6 days	80% loss	80% of total production cost
7 days	100% loss	100% of total production cost

Source: Authors.

BOX 5.2: Complexity in Product Design in Bangladesh

Three study areas were selected for the technical feasibility assessment for WII in Bangladesh. Initial activities included the selection of crop and study areas, and rice was proposed as the crop to be insured under the pilot. Dinajpur, Pabna, and Bogra were selected because of:

1. The large number of rice farmers
2. A preliminary risk assessment based on national-level risk maps
3. The existence of many MFIs providing crop loans
4. The existence of weather stations with historical records

Investigating the technical feasibility of WII involved:

1. Analysis of meteorological and yield data
2. Assessment of trigger level and payout scale
3. Pricing of contract for insurance purposes

The results of the analyses highlighted the complexity of designing rainfall-related WII contracts for the chosen areas. While the districts were situated in drought-prone areas, and the national-level yield assessment demonstrated that rainfall variability plays a key role in the rice yield variability, for the purpose of designing a simple rainfall index insurance product applicable to a whole district, the study did not find weather indicator-yield correlations at a systemic (district-wide) level in the three study areas.

Data constraints play a key role in the findings. It became evident that the historical yield data series were not useful for the purpose of contract design given the large area (covering two to three districts) from which the data were aggregated. Additionally, the distances of the study areas from meteorological stations became clear during the field visits.

There were existing risk management practices prevalent in the study areas. Interviews with farmers highlighted the importance of existing mitigation practices such as irrigation and the use of pumped ground water.

Data problems, plus alternate mitigation actions, make WII complicated. In an environment of farming systems and rural water management as complex as in Bangladesh, determining the value of a WII product requires an elevated level of intensive research work.

Source: Authors.

BOX 5.3: Contract Pricing

When establishing a price for a weather risk management instrument, providers will take into consideration their own risk appetite, business imperatives, and operational costs. While there are a variety of methodologies for pricing, in general the pricing for all contracts will contain an element of expected loss, plus some loading or risk margin that corresponds to a capital reserve charge required to underwrite the risk at a target level for the business, as well as administrative costs. Therefore in general the premium charge for a contract can be broken down as follows:

$$\textit{Premium} = \textit{Expected Loss} + \textit{Risk Margin} + \textit{Administrative Costs}$$

Expected loss is the average payout of the contract in any given season. The risk margin is charged by the providers because in some years, when extreme events happen, payouts in excess of this average can occur, and the risk taker must be compensated for this uncertainty. The values of the expected loss and the risk margin must be established from historical weather data. These values may include an adjustment to compensate for uncertainties in the data such as trends or missing values. The approach for determining the loading over the expected loss differs from insurer to insurer, and many use a combination of methods to determine the risk margin included. A sensible pricing methodology uses a risk measure such as the value at risk (VaR) of the contract to determine the risk margin. A VaR calculation is aimed at determining the loss that will not be exceeded at some specified level of confidence, often set at 99 percent. Administrative costs are essentially the costs for the provider to run the business, including charges for data, office costs, taxes, and reinsurance and brokerage charges if necessary.

Source: Authors.

The project team will need to adopt a great degree of flexibility and innovative approach while going through the process of structuring an index contract in agriculture, and be prepared to admit that the complexities at times are so overwhelming that there is no confidence on behalf of the project team about delivering an adequate response to transfer risks for farmers in a particular situation. Box 5.2 illustrates such complexities in a real case scenario in Bangladesh.

5.6 PRICING THE INDEX CONTRACT

In effect, the "price" of the contract, or rather the cost of the premium, will ultimately be set by the insurer. The process that an insurer undertakes to determine the premium is known as underwriting. The role of the task manager or WII promoter will be to ensure that a potential insurer has the required level of information and possesses the suitable level of confidence in it. Underwriting is basically evaluation by the insurer of the risk and exposures of potential clients in order to determine an acceptable risk (eligibility) and level of coverage, and thereby premium. Insurers use their own methods to appraise risks and price contracts, and therefore different insurers price the same contract at different premium levels for the same risks. However, box 5.3 provides a simple overview of the elements involved in pricing.

Insurers seeking to introduce WII in lower-income countries typically have at most 25 to 30 years of weather data. Within such short time frames, significant catastrophes and existing trends may fail to emerge from the data. Thus, when calculating expected losses, insurers take the pure risk (according to the data) and then add an ambiguity load—effectively a margin to account for inaccuracies or uncertainties. Ambiguity loads can also be used to account for changing weather risk—for example, related to climate change. An insurer attempting to price pure risk is unable to tell if future trends will be the same, worse, or better, and often ambiguity loads can be significant.

Insurers can and do adjust pure risk estimates and ambiguity loads over time, although new information does not always provide clarity or lead to reduced pricing. When insurers have access to very little data, it may be difficult to tell if new data fit into the same pattern or represent a fundamental change. For instance, a series of weather shocks may be an example of a low frequency, high severity risk within the same central tendency or it may suggest a shift in the central tendency and overall climate.