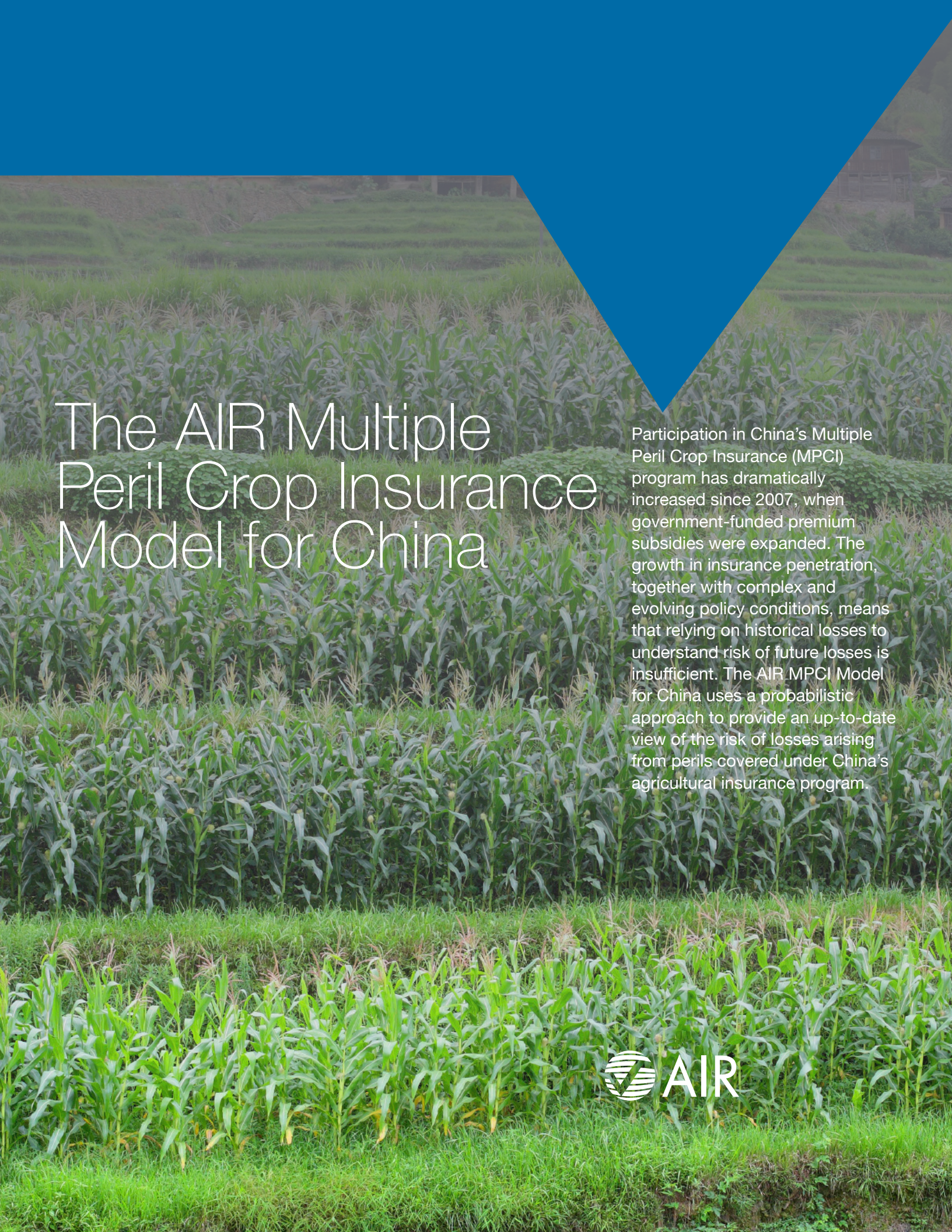


The AIR Multiple Peril Crop Insurance Model for China

Participation in China's Multiple Peril Crop Insurance (MPCI) program has dramatically increased since 2007, when government-funded premium subsidies were expanded. The growth in insurance penetration, together with complex and evolving policy conditions, means that relying on historical losses to understand risk of future losses is insufficient. The AIR MPCI Model for China uses a probabilistic approach to provide an up-to-date view of the risk of losses arising from perils covered under China's agricultural insurance program.

AIR

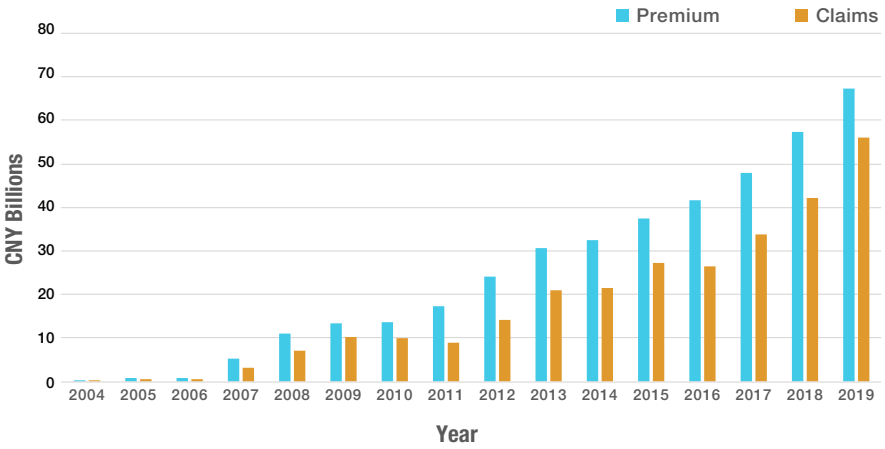
A primary distinction between agricultural insurance and most other insurance lines is the often widespread geographic correlation of losses—the result of large-scale adverse weather events. In mainland China, extreme weather is to blame for 90% of crop losses; the financial impact is significant. AIR estimates that a repeat of the 2000 drought would cost crop insurers more than CNY 20 billion (USD 3 billion) today. Thus, in order to quantify the potential gains and losses to a crop insurance portfolio, it is critical to quantify the impact of weather.

China is a leading global producer of wood and paper products; the country's forests can be insured under the national crop insurance scheme and incur large losses not only from extreme weather but also fire, pests, and disease. In addition, livestock (including poultry) policies now make up about a quarter of agricultural premiums in the country and have a large potential for losses due to weather and disease. To get a comprehensive view of agricultural risk in China, companies must consider the risk to crops, forests, and livestock.

AIR's Approach to Modeling Agricultural Losses Offers Companies Multiple, Comprehensive Views of Their Risk

In 2011, AIR leveraged its considerable experience and success in modeling MPCI portfolios in the United States to develop a model for mainland China. Since then, we have updated the model several times to keep it current with the fast-changing Chinese agricultural insurance market. The AIR MPCI Model for China captures the severity, frequency, and location of drought, flood, wind, frost, and heat events nationwide covering over 90% of the weather-related crop losses. In addition, AIR models losses to forests due to fire, wind, pests, disease, and rodents, as well as losses to livestock due to weather and disease.

AIR is dedicated to user flexibility, offering companies multiple views of their risk. Regular model updates ensure that analyses reflect the latest available weather, exposure, and policy condition information. Into each update, AIR incorporates new exposure data from the China Statistical Yearbook and new policy condition information from the industry. Clients can generate custom results by using peril and line-of-business filters, as well as by adjusting premium rates and sum insured per mu. In addition, the model provides a 10,000-year stochastic event catalog and a historical event set from 1981 to 2018 (through 2015 for forestry).



The growth in both premiums and claims arising from China's crop insurance program highlights the importance of modeling the impact of adverse weather events on China's cropland. (Sources: National Bureau of Statistics of China, China Banking and Insurance Regulatory Commission)

Accounting for the Major Crops Covered by Insurance

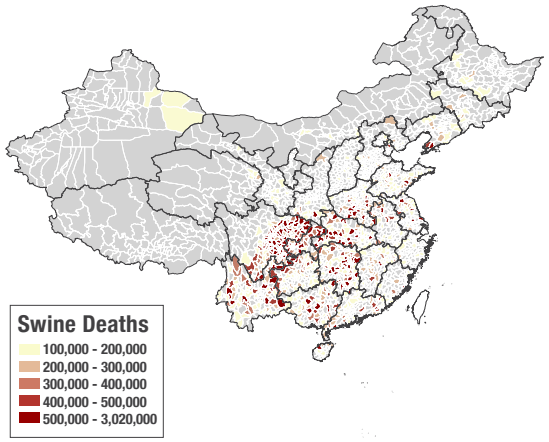
The AIR MPCI Model for China estimates damage to all crops with federal subsidies for crop insurance premium: corn, cotton, rapeseed, rice, soybean, wheat, barley, peanut, potato, sugar (includes cane and beet sugar), and rubber—the country's major crops. The severity of crop damage—and the insured losses that result—can vary depending on which phase in the growing season an extreme weather event occurs. Insurance policy conditions in China cover crop production costs up to the time of damage, thus payouts are directly correlated to the crop's stage of development. At the start of a crop's growing season, for example, farmers have invested limited time and money; thus, if an extreme weather event occurs, the potential losses to the insurer are limited. As the season continues, however, the potential for insured losses increases.

Policy conditions also vary depending on crop type, peril, and province. The AIR MPCI Model for China was built to accommodate these complex policy conditions.

Modeling Livestock Risk

Because China is the leading producer of chickens, pigs, goats, ducks, and sheep, and is the fourth-largest producer of cattle in the world by head, the potential for livestock losses is considerable. Livestock (including poultry) are susceptible not only to extreme weather events but also disease—a risk that can produce extreme livestock losses. For example, an outbreak of African swine fever—a highly infectious and deadly disease—started impacting pigs in China in 2018, resulting in a loss of half of China's 400 million pigs, or 40% of the world's total agricultural pig population, as of the first half of 2020. The stochastic catalog in the AIR model provides a realistic view of the spread of disease among livestock, as shown in the figure, enabling users to probabilistically assess potential losses.

The AIR MPCI Model for China estimates weather and disease losses to livestock, including all livestock types with federal subsidies for livestock insurance premium: dairy cattle, other cattle, breeding sow, other pig, poultry, and sheep/goats. Livestock death rates due to extreme weather are estimated by leveraging the model's weather events that impact crops and forests. The frequency and severity of disease outbreaks for livestock (including poultry) in China are modeled from data from the World Organization for Animal Health and recent historical events.



The modeled footprint of swine deaths (breeding sow and other pig combined) for an African swine fever-like event from the AIR stochastic catalog shows the potential severity of losses for a disease outbreak among livestock.

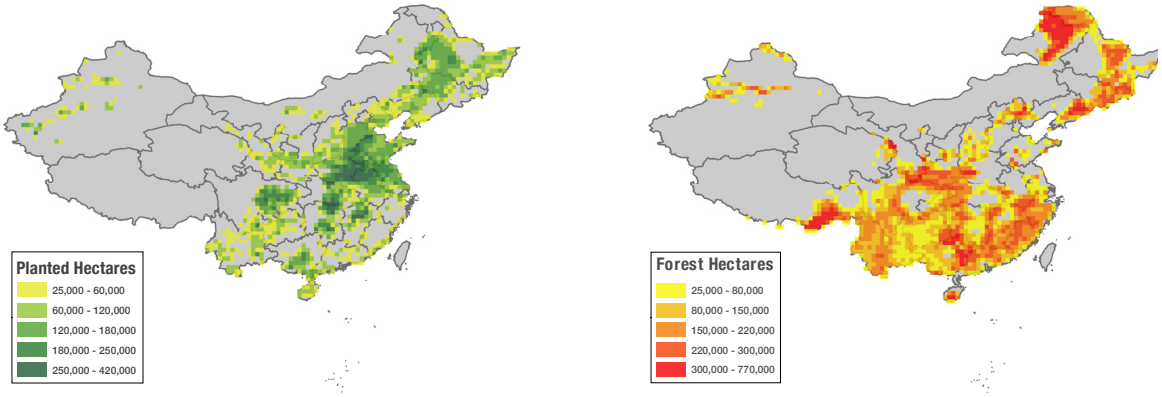
Leveraging Local Data Amid a Highly Variable Climate

Mainland China has multiple climatic zones, ranging from subtropical to subarctic, and is subject to a wide range of weather events. The AIR MPCI Model for China captures the effects of drought, flood (due to excessive local precipitation, the runoff from more remote precipitation, and/or snowmelt), wind, frost, and heat, for crops; fire, wind, and pest/disease/rodent for forests; and weather and disease for livestock. The model also captures the geographic variation in weather (for example, drought is more common in the arid north and west) and their different impacts (for example, dehydration in the case of drought, or crop rot in the case of flood).

Because perils can be correlated in complex and non-linear ways, the model uses a single, unified weather catalog for all modeled lines of business and weather-based perils. To create a comprehensive 10,000-year catalog of simulated weather events, AIR scientists collected data on historical weather and disease events from various agencies, such as the U.S. National Oceanic and Atmospheric Administration and the National Bureau of Statistics of China. Daily temperature, precipitation, and wind speed data at high spatial resolution were also analyzed, and all this information was coupled with data on soils, terrain/elevation, and the spatial distribution of land cover types.

Building Crop and Forest Location Data

Crops and forests are susceptible to different perils, and a single peril can have a different impact depending on the line of business and location. Using satellite-derived land use/land cover data, government statistics, and published academic sources, AIR has identified the locations of cropland by crop type, as well as the locations of forests. Comparing planted hectares of cropland to forested hectares shows that while there is some overlap, the areas with the highest concentrations of crop and forestry exposure differ. While crops and forests are both susceptible to extreme weather, location can greatly impact the vulnerability and potential risk.

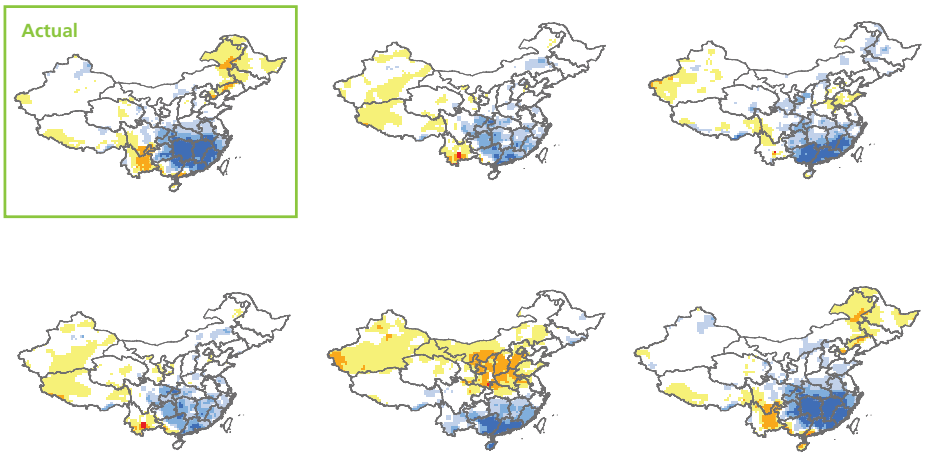


The spatial distribution of planted hectares of cropland (left) and forested hectares (right) in China show differences in location, which can impact vulnerability and potential risk.

Creating New Crop Year Scenarios from Historical Data

Historical flood, drought, snow, wind, frost, and heat events from 1979 to 2018 form the basis for generating the events that make up the model's catalog of simulated events. By perturbing the growing conditions that were experienced during the historical years, a catalog representing a wide range of outcomes is produced—each equally likely, but with potentially very different implications for insured losses.

The AIR event generation process carefully maintains correlations in growing conditions in both space and time. These correlations are extremely important from a risk management perspective, as they are the basis of any risk protection available from a well-diversified crop insurance portfolio.



Crop growing conditions during historical floods and droughts are "perturbed" to produce the model's 10,000-year catalog. Shown here are five realizations of perturbing the growing conditions during a historical flood event from May 2003.

Damage to Crops, Forests, and Livestock from Extreme Weather

The severity of damage from adverse weather events to crops, forests, and livestock depends upon many factors, such as the frequency, duration, location, and timing of an event during the season. The type of crop, tree, or animal that is at risk also impacts potential damage.

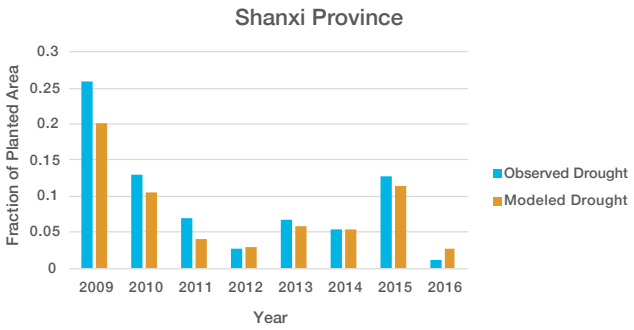
A given weather event can have differing effects on different crop species or on the same crop during its different developmental stages. Some adverse effects of weather carry through to the end of a crop's entire life cycle, while others may be partially mitigated by various repair or acclimation processes. It is the integration and interaction of all weather-related effects that determines the final damage to a crop as realized at harvest for all explicitly modeled crops. The weather scenarios in the AIR MPCI Model for China cover the extremes of water supply (from drought to flood), both low- and high-temperature extremes, as well as wind and storm damage that includes the effects of hail. The availability of water compared with each crop's specific water needs is assessed using time-series data on daily minimum and maximum temperature, daily accumulated precipitation, available water capacity of soil, crop-specific data (water requirement at each stage of crop development, planting dates, and resilience to adverse weather conditions), land use/land cover, and terrain elevation. The aridity and soil moisture are computed based on a water balance module that estimates the plant-available water content at any point in a growing season. Excess moisture due to precipitation upstream and snowmelt is estimated by a runoff model. The effects of all the modeled weather variables are integrated using crop-specific damage functions to estimate insured losses.

Weather events that impact crops also affect forests. The events that cause significant limb loss or tree death are wind, fire, pests, disease, and rodents. Damage functions account for the effect of damaging wind, including the effect of excessive precipitation that makes the uprooting of trees more likely. The location and severity of forest fires is largely determined by localized human behavior. The AIR MPCI Model for China uses a random forest–based method that incorporates location-level data and weather predictors drawn from the model's catalog of weather scenarios to estimate fire damage to forests. Pest, disease, and rodent damage is modeled statistically based upon province-level statistics.

Livestock (including poultry) are also vulnerable to flood, wind, temperature extremes, and humidity. Animals can drown in floodwaters and die from diseases that spread after floods. Wind, especially with cold or snow, cause livestock damage; in 1993, for example, several events of strong wind, including sandstorms, in the east of Xinjiang, Gansu, Ningxia, and western Inner Mongolia, caused losses of 120,000 livestock. For poultry, heat stress caused by high temperature and humidity negatively affects productivity and immune response, decreasing production and even killing animals. In extreme cases, continuous snow events and snowpack can bury livestock, ice can cause cuts and lacerations, and low temperatures can cause frostbite. Grazing cattle and goats are additionally susceptible to snow and drought, both of which can make it difficult to find food and drinking water. Leveraging the weather catalog used for crops and forests, the AIR MPCI Model for China employs a linear regression-based model to estimate death rate due to weather. In addition, a statistical model is used to estimate the death rate due to disease.

Modeled Losses Are Validated Against Historical Losses

Damaged areas for crops and forests and death rates for livestock (including poultry) are validated using historical data. The figure displays the results for Shanxi Province showing that the modeled drought-damaged areas for the years 2009 to 2016 agree well with the historically observed damaged areas. The AIR MPCI Model for China calculates insured losses through the application of agricultural insurance policy conditions to the model's catalog of simulated events. Each policy type is unique and may be based on combinations of province-average cost of production, perils, premium rates, sums insured, deductibles, and indemnity levels. To ensure the most reliable modeled loss estimates available, losses from the AIR MPCI Model for China are carefully validated against actual loss experience.



AIR-modeled damaged areas for the years 2009 to 2016 compare well to the observed damaged areas.

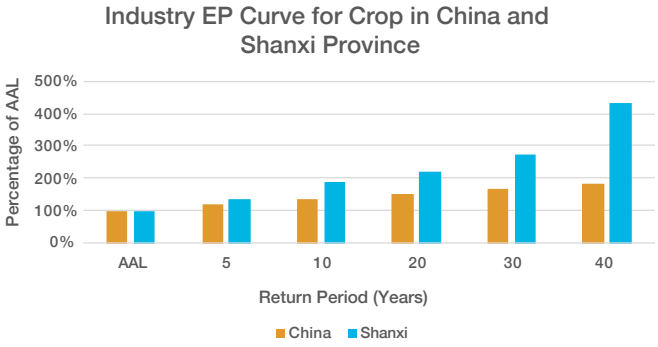
Applications for Crop Insurers and Reinsurers

MPCI programs are evaluated by applying each of the 10,000-year catalog outcomes and determining the insured retained loss. The probability distribution of total losses across the 10,000 simulated outcomes provides the measure of the risk of loss. This is expressed in terms of an exceedance probability distribution, characterized by the average (expected) annual gain/loss, and losses at selected exceedance probability (EP) levels, such as 10% (10-year return period), 5% (20-year return period), 1% (100-year return period), and 0.4% (250-year return period) exceedance probabilities.

Agricultural insurance and reinsurance evaluations are performed in AIR's Touchstone Re™ software. Clients can generate custom results by using peril and line-of-business filters and adjusting premium rates and sum insured per mu. Agriculture insurers can evaluate alternative strategies in terms of expected profit versus potential risk. Reinsurers can price excess of loss and quota share programs and manage their entire portfolio.

The average annual loss (AAL) in the exceedance probability (EP) curve reflects historical loss ratios in China's crop insurance market. "Tail" events with large return periods, such as major droughts, flood, or wind events, can produce losses that far exceed the average.

The industry EP curve shown in orange shows the size of tail events relative to the average annual loss for a countrywide exposure of crop lines of business. When exposure is concentrated in an individual province, such as Shanxi shown in blue, the size of losses in tail events can far outstrip the average loss. The EP curves shown here have been scaled to the same average annual loss.



Model at a Glance

Modeled Perils	– Crops: Drought, flood, wind, frost, and heat – Forestry: Fire, wind, and pest/disease/rodent – Livestock: Weather, disease
Model Domain	Mainland China
Supported Geographic Resolution	County and province
Vulnerability Module	Vulnerability varies by farming practice, peril, and crop developmental stage
Covered Lines of Business	– Crops: Corn, cotton, rapeseed, rice, soybean, wheat, barley, peanut, potato, sugar (includes cane and beet sugar), and rubber are all explicitly modeled – Forestry: All forest types – Livestock: Dairy cattle, other cattle, breeding sow, other pig, poultry, sheep/goat
Historical Catalog	Historical losses based on current exposure and coverage terms recast for the years 1981 through 2018 for crop and livestock (through 2015 for forestry)
Model Options	Modeled output can be adjusted for sum insured per mu and premium rate and differentiated by peril and line of business

Model Highlights

- Supports all central government-sponsored lines of business for agricultural insurance in China
- Provides a probabilistic catalog reflecting the spatial and temporal correlations of losses
- Isolates the impacts of extreme weather on crops, forests, and livestock at the county and province levels
- Captures the variability of plant vulnerability to environmental stress throughout the plant life cycle
- Includes the first probabilistic approach for determining the likelihood of insured losses to China's forests
- Provides a view of livestock risk that considers the impacts of both disease and extreme weather
- Reflects the differences in individual insurance programs, which can vary by province
- Incorporates the latest policy conditions and terms

ABOUT AIR WORLDWIDE

AIR Worldwide (AIR) provides risk modeling solutions that make individuals, businesses, and society more resilient to extreme events. In 1987, AIR Worldwide founded the catastrophe modeling industry and today models the risk from natural catastrophes, supply chain disruptions, terrorism, pandemics, casualty catastrophes, and cyber incidents. Insurance, reinsurance, financial, corporate, and government clients rely on AIR's advanced science, software, and consulting services for catastrophe risk management, insurance-linked securities, longevity modeling, site-specific engineering analyses, and agricultural risk management. AIR Worldwide, a Verisk (Nasdaq:VRSK) business, is headquartered in Boston, with additional offices in North America, Europe, and Asia. For more information, please visit www.air-worldwide.com. For more information about Verisk, a leading data analytics provider serving customers in insurance, energy and specialized markets, and financial services, please visit www.verisk.com.

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