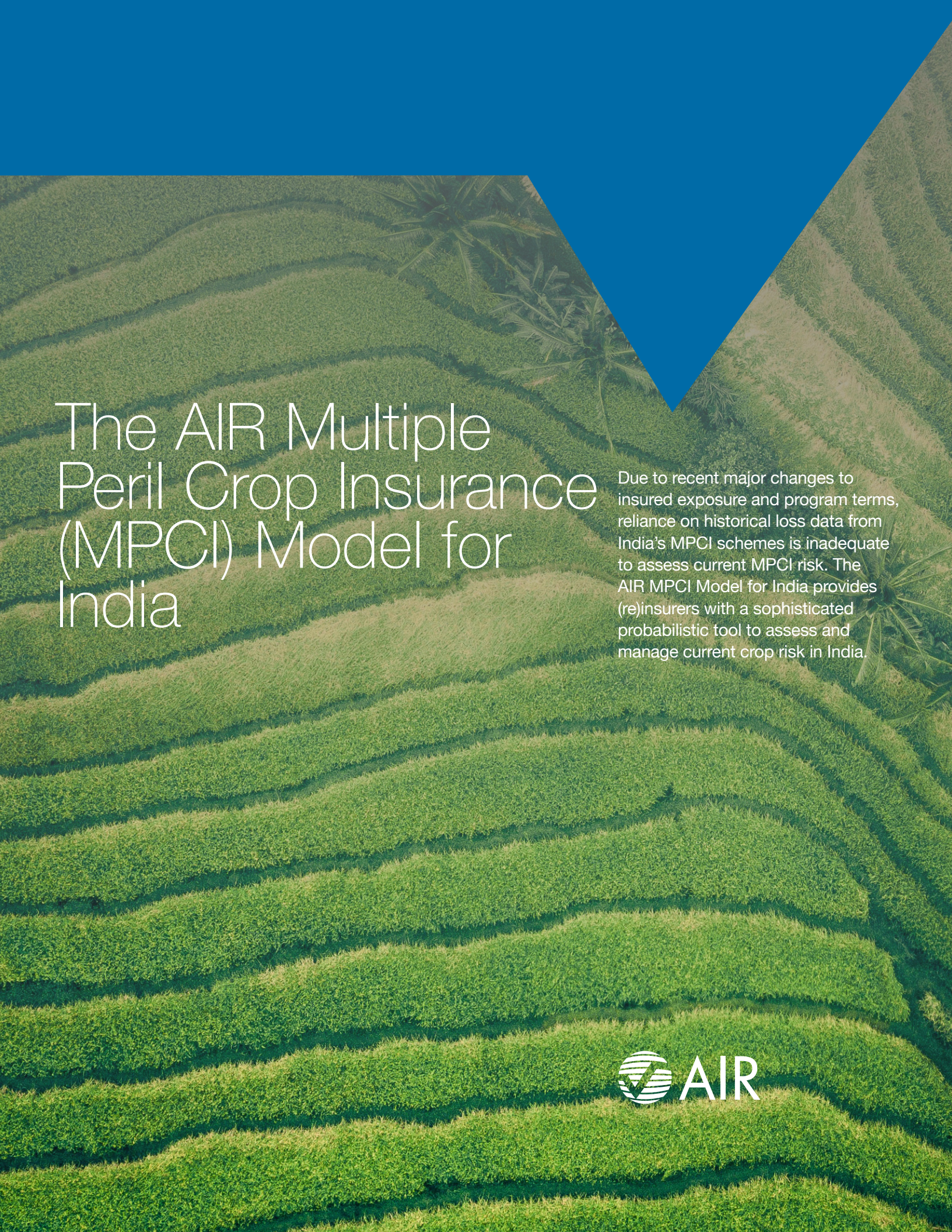


The AIR Multiple Peril Crop Insurance (MPCI) Model for India

Due to recent major changes to insured exposure and program terms, reliance on historical loss data from India's MPCI schemes is inadequate to assess current MPCI risk. The AIR MPCI Model for India provides (re)insurers with a sophisticated probabilistic tool to assess and manage current crop risk in India.

AIR

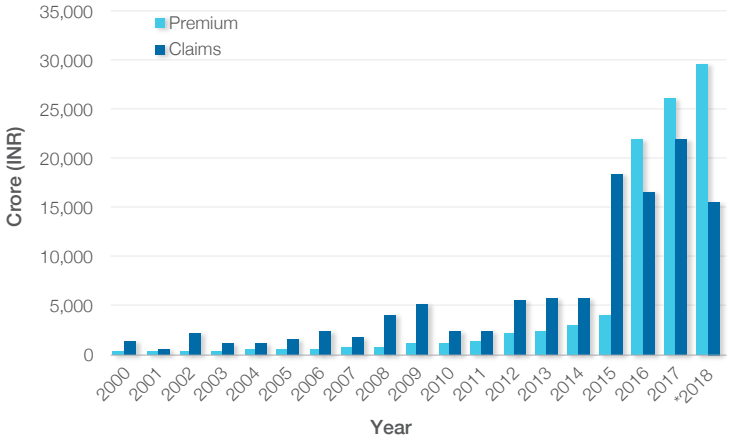
Several Indian crop insurance schemes have come and gone since the first experimental program was implemented in 1972. From that first implementation through 2015, loss ratios consistently exceeded 100% across several multiple peril crop insurance (MPCI) schemes. The Pradhan Mantri Fasal Bima Yojana (PMFBY), the current national MPCI program implemented in 2016, however, is off to a better start, with a cumulative loss ratio for its first three years (six crop seasons) of about 70%. But it remains to be seen whether future claims paid may again exceed premiums collected, as was the case during most of the MPCI era in India.

A Sophisticated Probabilistic Approach to Modeling Multiple Peril Crop Insurance Losses in India

Estimating the likelihood and magnitude of future losses presents challenges. A reliance on loss history to gauge present risk is inadequate for several reasons, most notably:

- Recent large increases in insured exposure and farmer participation
- Changes to crop management practices that moderate susceptibility to damage from physical and biological stressors
- Updates to crop insurance policy conditions
- Inconsistent performance of previous crop insurance schemes

Because traditional methods that solely rely on historical losses are unreliable in quantifying and managing this complex risk, AIR developed the MPCI Model for India to better meet the needs of this growing (re)insurance market whose annual insurance premium now exceeds USD 4 billion.



Growth of premiums and annual variation in claims for India's three national MPCI schemes in operation since 2000: NAIS, 2000–2015; MNAIS, 2010–2015; and PMFBY, 2016–present. *2018 values are preliminary.

A probabilistic approach can provide the full breadth of possible crop loss scenarios that might occur while accounting for present crop genetics and yield potential, management practices, exposure, weather scenarios, and policy conditions, enabling informed decision-making regarding current risk in the complex and dynamic Indian MPCI sector.

Managing Crop Yield Risk in India

Despite considerable gains in crop productivity in India during the past 50 years, significant losses still occur, caused primarily by adverse weather events. The extent and frequency of such events can vary greatly from season to season. For example, a bumper crop in one season could be followed by severe losses in the next. Large losses in southern India could coincide with record yields in the north.

The AIR MPCI Model for India enables users to conduct sophisticated probabilistic modeling of crop yield shortfall and associated claims for the PMFBY standing crop risk category. Relationships between weather and crop yield, in addition to analysis of past interannual variation in yield, are the foundations of stochastic simulations of insurable crop yields and losses. In all cases correlations between different locations and crops across India are maintained.

AIR's Unique Database for India Crop Yield

Researchers at AIR, following diligent and thorough analytical processes, combined the extensive data sets from the Directorate of Economics and Statistics (DES) and the Village Dynamics in South Asia (VDSA) project, along with multiple other district-level crop data to generate a comprehensive district-level crop area, production, and yield (APY) database for India. All data were meticulously verified to ensure accuracy and consistency.

India MPCI: One Year, Two Insurance Seasons

Unlike some major crop insurance programs, the PMFBY scheme is applied to two distinct seasons each year: *kharif* season, roughly July to October, and *rabi* season, roughly October to March. Kharif begins with the first rains of the southwest monsoon whose advent varies by location—earlier in the south—and from year to year. The start of rabi also varies by location and from year to year because of temporal and spatial variation in weather. In addition, many locations have a third crop season between rabi and the following kharif; for these locations, two seasons are covered by one of the PMFBY-designated seasons and the third is covered by the other PMFBY-designated season. For example, in the state of Tamil Nadu, the first paddy crop planted during kharif, "Paddy I," is covered by PMFBY kharif, and the two following, consecutive crops that will be planted and harvested before the following kharif season begins, "Paddy II" and "Paddy III," are covered by PMFBY rabi.

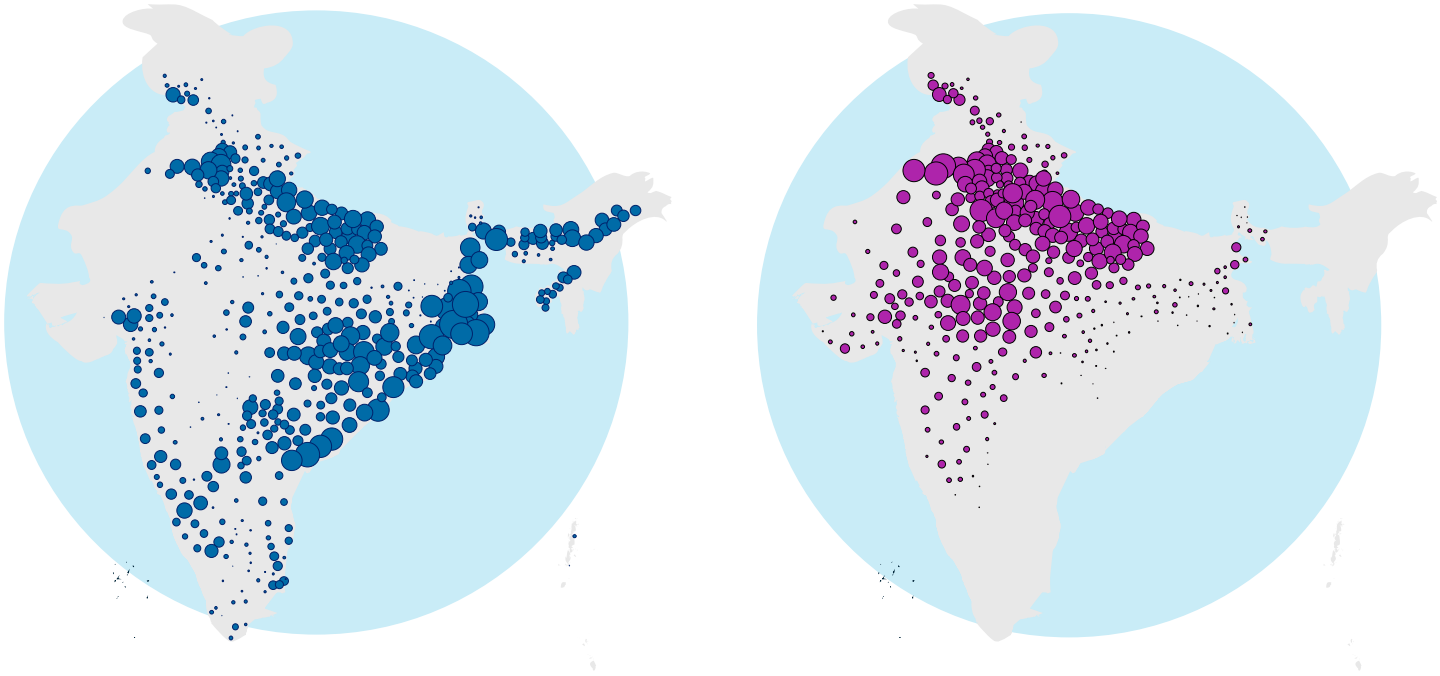
AIR Provides the Industry's Leading Crop Models

AIR released the industry's first probabilistic MPCI model in 2007—which has since become the standard for crop insurance in the United States. Since then AIR's suite of crop models has expanded to include MPCI models for China, Canada, and now India, as well as Crop Hail models for the United States and for Canada.

The AIR India MPCI Model addresses these multiple PMFBY seasons seamlessly, having been built from historical yield events and weather data that retain their temporal patterns. The model's historical catalog represents a continuous simulation of yield and loss from 1979 through 2017, with no artificial breaks. The stochastic catalog represents 10,000 continuous periods from pre-kharif to the end of the following rabi, including any third crop season in relevant districts.

Capturing Spatial Yield Correlations in the Stochastic Loss Catalog for Better Risk Protection

AIR developed a set of 10,000 potential yield outcomes for each modeled crop- and water-management practice combination in each district participating in the PMFBY scheme for both kharif and rabi seasons. The AIR catalog generation process carefully maintained critical correlations: correlations between districts within and between states; correlations between crops within a location; and correlations between each kharif and the following rabi season. These spatial and temporal correlations are critical from a risk management perspective because they are the basis of risk protection available from a well-diversified crop insurance portfolio.



District-level PMFBY insurable exposure of kharif rice (paddy) (left) and rabi wheat (right), the two most productive crops in India. Each district insuring the crop under PMFBY is represented by a filled circle centered on the district centroid, with the area of the circle proportional to insurable liability in the district. (Crops grown in states and union territories currently not participating in the PMFBY are excluded, including Bihar and Punjab, both of which are major rice (paddy) and wheat producers.)

Accounting for Diverse Crop Exposure

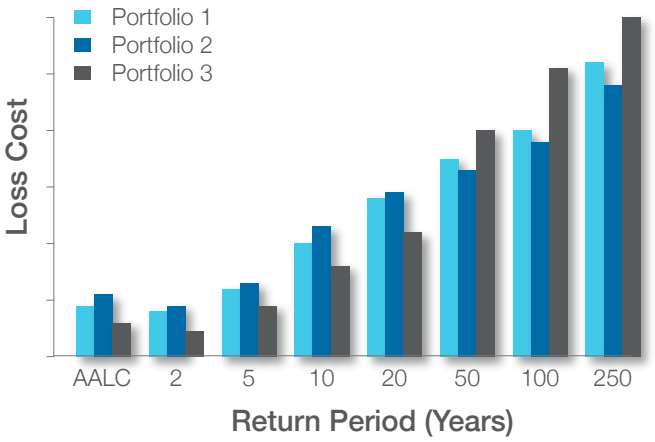
AIR's industry exposure database (IED) for the PMFBY includes data for each district insuring any crop under the scheme and accounts for participation by individual states and union territories. For each insurable crop during each season, the IED includes current harvested area, fraction of crop area that is irrigated, level of indemnity (70%, 80%, or 90%), and sum insured (SI) per hectare.

Cluster Selection during the Insurance Premium Bidding Process

Because the AIR MPCI Model for India retains the key spatial and temporal crop loss correlations, users can analyze *potential* portfolios of PMFBY clusters prior to the premium rate bidding process.

Crops Covered by the AIR MPCI Model for India

The model explicitly simulates losses for the major insured kharif crops of rice (paddy), cotton, soybean, maize, pearl millet (bajra), and peanut (groundnut), as well as the major insured rabi crops of wheat, rice (paddy), chickpea (gram), mustard and rapeseed, and sorghum (jowar). Explicitly modeled crops together account for about 81% of insurable PMFBY liability; the remaining 19% is implicitly modeled through statistical relationships developed from analysis of long-term yield patterns and correlations of all PMFBY-insured crops.



A comparison of three notional multi-cluster portfolios, each of which comprises several PMFBY clusters, using the AIR MPCI Model for India.

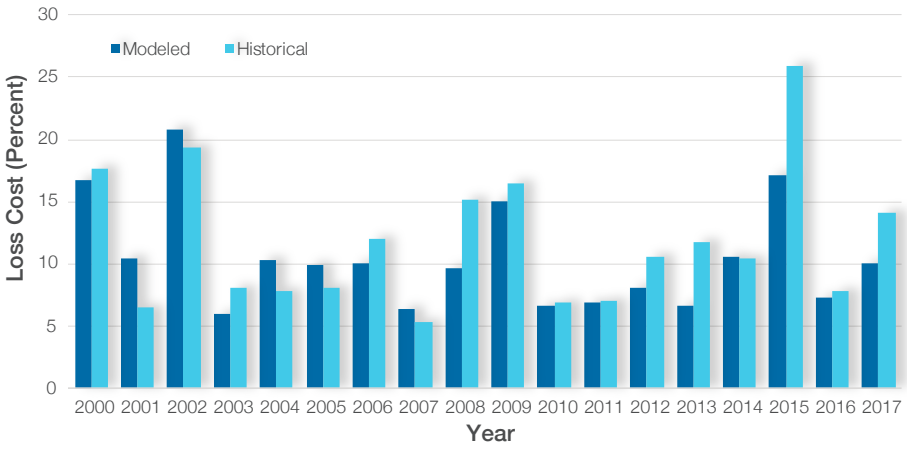
These different potential portfolios (mixtures of clusters) can be compared with respect to their aggregate risk before a company establishes the clusters to be targeted for bidding. This approach is illustrated in the bar chart comparing three hypothetical multi-cluster portfolios. Portfolio 1 has a modeled average annual loss cost (AALC) and loss cost across all plotted return periods that is intermediate among the three portfolios; Portfolio 2 has the highest AALC but the lowest loss cost for return periods of 50 or more years, indicating some protection against catastrophic losses; and Portfolio 3 has the lowest AALC but the highest loss cost for return periods of 50 or more years because of positive correlations between clusters in high-loss years, indicating a possibility of larger portfolio-level catastrophic losses.

Depending on risk appetite, an informed decision can be made about how to group clusters into a target portfolio during the bidding process to protect against large average loss and/or large tail losses. Premium rates could also be set based on assessments of average annual loss, standard deviation of average loss, and/or losses associated with specified return periods down to the level of individual crops in individual districts. Similarly, reinsurers can assess respective risk among alternative cluster portfolios, either proposed or actual.

Modeled Losses Are Validated Against Historical Loss Experience

To assure reliable modeled loss estimates, losses from the AIR MPCI Model for India are compared with historical loss experience. Because the model reflects (recast) losses that would occur if past conditions were repeated with today's exposure and insurance terms, modeled losses may be expected to differ from historical (reported) losses to varying degrees due to differences between current insurable exposure and past exposure, as well as differences between PMFBY claim calculation procedures and those used in earlier schemes.

Modeled losses from the AIR India MPCI model compare well with historical loss experience. A comparison between modeled national kharif season loss cost for current PMFBY insurable exposure and policy conditions and kharif season loss cost derived from the total sum insured and claims for the previous NAIS and MNAIS schemes, and for the first year of PMFBY operation, show good agreement.



A comparison of historical kharif season loss cost for combined NAIS, MNAIS, and PMFBY with modeled loss cost from the AIR MPCI Model for India—recast using current PMFBY insurable exposure and 2018 revised policy conditions—show good agreement (data after 2017 unavailable).

Model at a Glance

Model Domain	The 25 states and union territories currently participating in the national PMFBY scheme (Andaman and Nicobar Islands, Andhra Pradesh, Assam, Chhattisgarh, Goa, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Puducherry, Rajasthan, Sikkim, Tamil Nadu, Telangana, Tripura, Uttarakhand, Uttar Pradesh, and West Bengal)
Modeled Perils	PMFBY "Standing Crop (Sowing to Harvesting)" yield losses, which account for at least 90% of PMFBY claims amounts. PMFBY "Localized Calamities" risk is implicitly included in model loss calculations
Covered Crops	Kharif: cotton, maize, peanut (groundnut), pearl millet (bajra), rice (paddy), soybean, other (all PMFBY-covered crops not explicitly modeled); Rabi: chickpea (gram), mustard and rapeseed, rice (paddy), sorghum (jowar), wheat, other (all other PMFBY-covered crops are implicitly modeled)
Supported Geographic Resolution	District-level exposure data available to Touchstone Re™ users
Supported Policy Conditions	PMFBY Standing Crop yield loss and Localized Calamities claims based on current insurable district-scale liability, crop- and location-specific indemnity level, sum insured per hectare, and revised guidelines pertaining to threshold yield definition

Model Highlights

- Probabilistic yield catalog for kharif and rabi seasons that accounts for spatial and temporal correlations of crop losses—a prerequisite for building a well-diversified crop insurance portfolio
- Grounded in a unique, quality-assured crop APY database
- Calculates losses at district, cluster, and state resolutions, consistent with current operational guidelines of the PMFBY
- Extensively validated against historical yield and loss data

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, 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.

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