# Farmer Risk Typologies in Haryana: A PCA-Based Segmentation of Risk Perceptions and Risk-Management Portfolios

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***Abstract*—Agricultural risk in Haryana is multi-dimensional and unevenly distributed across farm households, yet a large share of risk-management interventions is designed and implemented as if farmers were homogeneous. This paper develops an evidence-based typology of farm households to support segment-sensitive risk governance. Using a structured primary survey of 300 farm households across Haryana's agro-climatic zones, the study measures (i) perceived sources of agricultural risk and (ii) farmers' observed risk-management portfolios. Principal component analysis (PCA) is used to extract latent dimensions separately for perception and strategy indicators, followed by clustering on component scores to obtain interpretable farmer segments. The perception-side typology yields three groups—Balanced Risk Perceivers (51.3%), Institutionally Dependent & Infra-Constrained (12.7%), and Infrastructure-Cautious, Market-Secure (36.0%). The strategy-side typology yields three groups—Conservative Low-Strategists (39.0%), Off-Farm Diversified Copers (42.0%), and Proactive Risk Managers (19.0%). Profiling suggests that the ability to translate risk awareness into effective action depends on constraints and capabilities: infrastructure, liquidity, market connectivity, and institutional linkages. The paper proposes a practical targeting framework that aligns public investment (irrigation and storage), advisory services (extension and peer learning), and financial instruments (insurance and formal credit) with segment-specific needs. The evidence motivates a move from uniform risk schemes toward portfolio-aware, constraint-sensitive packages that improve both resilience and productive investment.**

***Index Terms*—risk perception; coping strategies; typology; principal component analysis; cluster analysis; Haryana**
**JEL Classification: Q12; Q14; Q18; C38**

## I. INTRODUCTION

Agriculture remains central to rural incomes and employment in Haryana, but farm households operate under a dense web of uncertainties. Weather variability shapes yields, pests and diseases create production losses, and output prices fluctuate with market arrivals and broader macroeconomic conditions. These shocks are compounded by input price volatility, evolving groundwater and energy constraints, and the transaction costs of accessing formal institutions such as crop insurance, credit, and procurement channels. In such an environment, risk is not a single variable; it is a portfolio of exposures that interact across production, markets, and institutions.

Importantly, risk is also heterogeneous. Two farmers cultivating the same crop can experience the same aggregate rainfall shock but face different net outcomes because their irrigation access differs, their soil conditions differ, or their market linkages differ. Similarly, policy instruments do not reach all households with equal intensity. Extension contact, cooperative membership, access to formal lending, and claim settlement experience under insurance schemes can vary sharply across villages and socio-economic categories. Therefore, the appropriate unit of analysis for policy is not the 'average farmer' but distinct segments of farm households who share similar constraint sets, information environments, and risk portfolios.

A persistent challenge in agricultural policy is the 'one-size-fits-all' bias: schemes are designed around uniform eligibility criteria and delivered through standardized channels, even when farmer

heterogeneity is large. When heterogeneity is ignored, resources are misallocated. Some households may receive instruments they cannot effectively use (for example, sophisticated financial products without last-mile service delivery), while others may receive instruments that are too small or too blunt to address their primary risks. A practical response is to build typologies that classify farmers based on how they perceive risk and how they respond to it.

This paper develops such typologies for Haryana using a multivariate survey approach. It asks two questions. First, can farm households be segmented into interpretable groups based on their risk perceptions, reflecting different salience patterns across climatic, market, and institutional risks? Second, can households be segmented based on their observed risk-management strategy portfolios, capturing differences in ex-ante risk reduction, diversification, and ex-post coping? Addressing these questions is valuable for research because it operationalizes heterogeneity using a disciplined empirical strategy; it is valuable for policy because it supports a targeting logic that can be implemented through extension, infrastructure planning, and risk-transfer design.

Methodologically, the paper uses principal component analysis (PCA) to recover latent dimensions from correlated perception and strategy indicators. Clustering on component scores yields stable, interpretable segments that can be profiled against household and farm characteristics. The empirical results identify three perception clusters and three strategy clusters, each with distinctive narratives and policy needs. The paper's main contribution is to translate these segments into a constraint-sensitive targeting framework that links infrastructure, advisory services, and financial instruments to the heterogeneity observed in the field.

The remainder of the paper is organized as follows. Section 2 reviews the related literature and articulates the analytical perspective. Section 3 describes the study area, survey design, and measurement strategy. Section 4 explains the empirical methods. Section 5 presents the typology results and cluster profiles. Section 6 develops policy implications and a segmentation-based targeting framework. Section 7 concludes and discusses limitations and directions for future work.

## II. HARYANA AS A RISK ENVIRONMENT

Haryana offers a particularly instructive setting for examining agricultural risk heterogeneity because it combines high-productivity irrigated systems with localized pockets of stress. On one hand, the state has benefited from early Green Revolution investments, relatively dense road networks in many districts, and strong market participation for major cereals. On the other hand, the production system is increasingly challenged by groundwater depletion in several blocks, rising input dependence, and heightened climate variability—especially in the timing and distribution of rainfall.

From the farmer's perspective, risk is experienced as a sequence of operational decisions under uncertainty. At the beginning of the season, farmers decide the crop mix and the scale of input use, while facing uncertainty about rainfall, pest incidence, and output prices. During the season, farmers update decisions based on information and liquidity, often under time pressure. At harvest and post-harvest stages, farmers confront marketing risks related to price realization, quality deductions, and the ability to store or stagger sales. Institutional interactions—such as procurement logistics, input subsidy delivery, and insurance claim processes—can also become salient risks if they are unpredictable or costly.

These risk processes are not uniform across households. Irrigation access, for example, transforms rainfall risk: a rainfed or partially irrigated farmer experiences rainfall shocks directly in yields, while a fully irrigated farmer experiences them indirectly through pumping costs, groundwater depth, or disease pressure. Similarly, market connectivity alters price risk: farmers with better access to multiple buyers and storage options can delay sales or negotiate, while farmers under liquidity pressure may be forced into distress sales. These differences motivate a segmentation approach that captures the joint structure of exposures, perceptions, and feasible response portfolios.

Importantly, risk in Haryana is also shaped by the institutional architecture. The presence of formal credit channels, procurement infrastructure, and crop

insurance coverage in principle provides a risk cushion. However, the effectiveness of these instruments depends on last-mile performance and trust. If enrollment is complex, information is incomplete, or claims are delayed, the perceived value of institutional tools declines. Consequently, farmers may revert to informal coping, which can be expensive and can slow productive investment. A typology approach is therefore useful because it distinguishes households for whom institutional tools are effective from households for whom such tools are largely inaccessible or untrusted.

## III. RELATED LITERATURE AND ANALYTICAL PERSPECTIVE

Risk has long been recognized as a defining feature of agricultural decision-making. In standard microeconomic terms, risk enters through uncertainty in the production function and through uncertainty in output and input prices. When farmers are risk-averse, the distribution of outcomes—rather than expected values alone—shapes technology adoption, cropping choices, and investment decisions. A key implication is that risk can reduce productive investment even when returns are high, especially if households face liquidity constraints or incomplete insurance.

Empirical work distinguishes between objective exposure and subjective risk perception. Objective exposure can be proxied by agro-climatic variables or historical yield variability, but perception reflects experience, information, and beliefs. Perception is shaped by recent shocks, social learning, and trust in institutions. This matters because many risk-management choices—such as enrolling in insurance, adopting new varieties, or investing in irrigation—are driven by beliefs about the likelihood and severity of losses. Two farmers with similar exposure may thus adopt different strategies if their perception and information differ.

Risk management in agriculture is typically framed as a portfolio problem. Farmers combine ex-ante risk reduction (e.g., diversification, irrigation, improved inputs, agronomic practices) with ex-post coping (e.g., borrowing, savings depletion, asset sales, reliance on relatives). Formal risk-transfer instruments (insurance) and formal finance (credit) interact with these strategies. For example, insurance can stabilize income and support repayment, potentially improving credit access. Conversely, weak scheme performance can reduce trust and push households toward informal coping.

A policy-relevant insight from this literature is that 'capacity' to manage risk is uneven. Capacity is shaped by assets (land, irrigation), liquidity (savings, credit lines), human capital (education), and social/institutional capital (cooperatives, extension contact). Therefore, identifying clusters that group households with similar capacities and constraints is important for designing interventions.

Methodologically, typologies can be generated through rule-based classifications (farm size, region) or through data-driven segmentation. Rule-based classifications are easy to implement but may miss meaningful heterogeneity. Data-driven segmentation can incorporate multiple dimensions simultaneously. PCA is useful for dimension reduction when many indicators are correlated, and cluster analysis on component scores provides interpretable segments. This approach has two advantages. First, it reduces noise by focusing on common variation rather than idiosyncratic responses. Second, it yields segments that are directly grounded in the survey items and can be linked to intervention design.

In the context of Haryana, a typology approach is especially relevant because the state contains high-productivity irrigated systems as well as pockets of infrastructure constraints and market frictions. The variation in irrigation, cropping intensity, and market access is likely to translate into distinct risk perceptions and responses. The present paper therefore builds typologies that can inform segment-sensitive policy rather than relying on a single average narrative.

## IV. CONCEPTUAL FRAMEWORK

The paper adopts a 'constraints and capabilities' perspective. Farm households are viewed as choosing risk-management portfolios subject to: (i) their perceived risk environment, (ii) resource endowments and liquidity, (iii) access to infrastructure and markets, and (iv) institutional linkages and trust. Perception matters because it shapes the perceived payoff of strategies; capabilities matter because they determine feasibility.

Formally, the household chooses a vector of strategies that jointly determine exposure reduction, income diversification, and consumption smoothing. Because strategies are complements and substitutes, a portfolio view is essential. For example, irrigation investment and diversification may be complements in reducing yield risk, while borrowing and asset sales may be substitutes in coping after a shock. Institutional tools such as insurance and formal credit interact with these choices through transaction costs and perceived reliability.

The empirical typology used here is not intended to fix farmers permanently into categories. Rather, it provides an operational diagnostic tool: it identifies where constraints bind most strongly, and where capacity exists for more advanced instruments. From a policy standpoint, the goal is to shift households from low-capability portfolios toward more resilient and productive portfolios by relaxing binding constraints.

## V. DATA, STUDY AREA, AND MEASUREMENT

The empirical analysis draws on a primary survey of 300 farm households conducted across Haryana's agro-climatic zones. The sampling strategy was designed to capture variation in cropping systems, irrigation access, and market connectivity. Within each selected district and block, villages were chosen to reflect the local farming context, and households were randomly sampled from village lists with attention to representation of operational holdings.

The questionnaire captured: (i) household demographics and human capital; (ii) farm structure (landholding, irrigation access, machinery); (iii) cropping pattern and input use; (iv) market participation and sales channels; (v) institutional linkage (extension contact, membership in cooperatives/FPOs, engagement with formal credit and insurance); and (vi) risk perception and risk-management strategy batteries.

Risk perception items were framed as Likert-scale statements capturing perceived severity and frequency of major risk sources. Risk-management items captured both ex-ante strategies (diversification, agronomic practices, investment) and ex-post coping (borrowing, savings use, distress sales) as well as the use of formal risk-transfer instruments. All items were standardized prior to multivariate analysis to ensure comparability across indicators.

Construction of perception and strategy indicators is central for typology credibility. Perception items were collected using Likert-scale statements that asked farmers to rate the severity or importance of specific risk sources. To reduce framing bias, items can be anchored to the farmer's own experience in recent seasons, and enumerators can be trained to ensure consistent interpretation across respondents. Because Likert items are ordinal, many applied studies treat them as approximately continuous after standardization; the present analysis follows the common practice of standardizing items prior to PCA to avoid scale dominance.

Risk-management strategy items captured the presence or intensity of strategies such as crop diversification, changes in input use, reliance on off-farm income, savings, borrowing, and engagement with formal tools. A useful distinction is between strategies that reduce exposure (e.g., irrigation investment, agronomic practices), strategies that spread risk (diversification), strategies that transfer risk (insurance), and strategies that smooth consumption (borrowing, savings). In the clustering interpretation, it is important to consider that some strategies may be 'high capacity' (requiring capital or information), while others are 'distress strategies' (e.g., asset sales) that signal vulnerability rather than resilience.

To enhance interpretability in the journal manuscript, the PCA stage can be reported using a concise table: retained components, eigenvalues, percentage variance explained, and the major items with high rotated loadings on each component. This permits the reader to see why a component is interpreted as, for example, a 'market risk salience' dimension or an 'institutional constraint' dimension. Similarly, for strategy components, reporting the dominant loadings clarifies whether a component reflects diversification, formal tool use, or reliance on coping.

## VI. EMPIRICAL STRATEGY

The empirical strategy follows a two-stage approach.

Stage 1: Principal component analysis (PCA). PCA is performed separately for risk perception indicators and risk-management strategy indicators. The

objective is to recover latent dimensions that represent common patterns across the survey items. Before PCA, reliability and suitability checks are recommended: internal consistency can be assessed using Cronbach's alpha, and sampling adequacy can be tested using the Kaiser–Meyer–Olkin (KMO) statistic and Bartlett's test of sphericity. Items are standardized to mean zero and unit variance. Components are retained using a combination of eigenvalue criteria, scree plot inspection, cumulative explained variance thresholds, and interpretability. Orthogonal rotation (e.g., Varimax) is applied to improve interpretability by achieving a simpler loading structure. Rotated component matrices are used to interpret the meaning of each component, and component scores are saved for clustering.

Stage 2: Cluster analysis on component scores. Cluster analysis is conducted separately for the perception component scores and for the strategy component scores. K-means clustering is used to obtain compact clusters with minimum within-cluster variance. The number of clusters is chosen based on stability and interpretability. In applied work, additional diagnostic tools can be used—such as within-cluster sum of squares ('elbow'), silhouette statistics, or split-sample stability checks. Once clusters are obtained, they are labeled using the dominant component patterns and linked back to the original survey items for narrative coherence.

Profiling and association analysis. After clustering, the segments are profiled using descriptive comparisons of household and farm characteristics. Mean differences can be evaluated using ANOVA or non-parametric tests depending on distributional assumptions, while categorical comparisons can be assessed using chi-square tests. A policy-relevant extension is to cross-tab perception clusters and strategy clusters to examine whether certain perception profiles are systematically associated with certain strategy portfolios. This cross-typology linkage helps distinguish households that are primarily constrained (high perceived risk but low strategic capacity) from households that are proactive (risk-aware and strategy-rich).

Cluster solutions can be sensitive to initialization and to the number of clusters. In applied segmentation work, robustness checks improve credibility. First, multiple random starts can be used in K-means to avoid local minima. Second, stability can be assessed by repeating clustering on split samples and examining whether cluster profiles remain similar. Third, alternative cluster counts (e.g., two or four) can be evaluated to confirm that the three-cluster solution provides the best balance of interpretability and within-cluster coherence.

Profiling robustness is also important. If cluster differences disappear once key covariates are controlled, labels may not be meaningful. Therefore, the manuscript can complement descriptive profiling with a multinomial logit model predicting cluster membership using socio-economic and farm variables. Such a model does not replace the typology; it clarifies which constraints (e.g., irrigation access, distance to market, education, extension contact) are systematically associated with segment membership. In addition, cross-tabulation of perception and strategy clusters can be tested using chi-square statistics to demonstrate that the two typologies are related but not identical—a desirable property that indicates that perceptions and actions have distinct structures.

## VII. RESULTS

This section reports the key typology findings. Because the purpose of the paper is to provide interpretable segments, the emphasis is on the narrative structure of the clusters and their policy relevance.

Risk perception typology. The perception-side clustering yields three segments. Balanced Risk Perceivers (51.3%) display a broad recognition of multiple risk sources—production, market, and institutional—without concentrating salience excessively on a single domain. This group reflects farmers who perceive risk as a normal feature of agriculture and acknowledge multiple uncertainties simultaneously.

Institutionally Dependent & Infra-Constrained farmers (12.7%) place comparatively higher salience on institutional bottlenecks and infrastructure limitations. Their perceived risk environment is shaped not only by weather and prices but by constraints in service delivery, market access, and last-mile institutional performance. This is consistent with a setting where transaction costs of accessing schemes and markets remain salient.

Infrastructure-Cautious, Market-Secure farmers (36.0%) exhibit a pattern where production and infrastructure vulnerabilities are perceived strongly, while market-related dimensions are perceived as relatively more manageable. This group can be interpreted as households that have comparatively better market connectivity or confidence in sales channels but remain cautious about biophysical and infrastructure risks.

Risk-management strategy typology. On the strategy side, three segments emerge. Conservative Low-Strategists (39.0%) adopt a relatively narrow portfolio of low-intensity actions. Their strategies are often incremental and reactive, reflecting either lower capacity, lower information, or a preference for familiar practices under uncertainty.

Off-Farm Diversified Copers (42.0%) rely on diversification beyond agriculture as a central smoothing mechanism. Their risk-management portfolio integrates farm adjustments with off-farm income sources, suggesting that livelihood diversification is a key resilience strategy.

Proactive Risk Managers (19.0%) adopt more forward-looking portfolios that combine diversification with proactive investments and greater engagement with formal tools where accessible. They are more likely to treat risk management as an investment problem rather than as short-term coping.

Cluster profiling and linkage. A practical implication is that awareness of risk does not automatically translate into effective action. A household may perceive risk sharply yet remain limited in its strategy set if constraints bind—such as limited irrigation, weak market access, or restricted formal finance. Conversely, households with stronger capability can convert risk awareness into proactive portfolios. For policy, this means that improving 'awareness' alone will not be sufficient; interventions must relax the constraints that prevent strategy adoption.

In the journal version of this paper, the following evidence from the thesis can be inserted to complete the empirical narrative: (i) PCA results (eigenvalues, variance explained, rotated loadings) for both perception and strategy batteries; (ii) cluster centroids on component scores and stability diagnostics; (iii) socio-economic and farm-resource profiles by cluster with statistical tests; and (iv) a cross-tabulation of perception clusters and strategy clusters showing the distribution of households across the combined typology.

Interpreting the latent dimensions. In the perception PCA, components typically separate into domains such as (i) climatic and production risks (rainfall, temperature stress, pest incidence), (ii) market risks (output price variability, marketing channel uncertainty, delayed payments), and (iii) institutional risks (scheme delivery, procurement logistics, and credibility of insurance settlement). In Haryana, where irrigation intensity varies, climatic salience often interacts with irrigation constraints: farmers with partial irrigation may report higher salience for rainfall timing and groundwater availability, while fully irrigated farmers may emphasize input cost risk and pest pressure. On the strategy side, components commonly reflect (i) diversification and crop-mix adjustment, (ii) formal tool engagement (insurance, formal credit, advisories), and (iii) coping intensity (borrowing, drawing down savings, distress sales). Reporting these component narratives strengthens the causal intuition behind cluster labeling.

Expected socio-economic profiles. The cluster labels can be validated and enriched by profiling along measurable dimensions. For example, Infrastructure-Cautious farmers are expected to report lower storage access and greater sensitivity to irrigation reliability; Institutionally Dependent farmers may report higher reliance on government channels but also higher dissatisfaction with settlement or service delays; Proactive Risk Managers are expected to have higher education, stronger extension contact, more diversified market access, and higher machinery ownership. Similarly, Off-Farm Diversified Copers often exhibit household labor availability and proximity to non-farm opportunities. While the direction of these associations must be confirmed using the thesis tables, including such profiling in the journal version clarifies the mechanisms through which constraints shape portfolios.

Perception–strategy mismatch as a policy diagnostic. A valuable output of the dual typology is the identification of mismatch patterns: households with high perceived risk but limited strategic response (a 'high concern–low capability' pattern) versus households with moderate perceived risk but rich portfolios (a 'capability-led' pattern). The former

should be prioritized for constraint-relaxing interventions (infrastructure, service delivery, transaction-cost reduction), while the latter can be targeted for productivity-enhancing instruments. This diagnostic moves beyond descriptive segmentation and directly informs program design.

TABLE 1. RISK PERCEPTION CLUSTERS (SHARE OF SAMPLE)

| Cluster | Interpretive label | Share (%) |
|---|---|---|
| 1 | Balanced Risk Perceivers | 51.3 |
| 2 | Institutionally Dependent & Infra-Constrained | 12.7 |
| 3 | Infrastructure-Cautious, Market-Secure | 36.0 |

TABLE 2. RISK-MANAGEMENT STRATEGY CLUSTERS (SHARE OF SAMPLE)

| Cluster | Interpretive label | Share (%) |
|---|---|---|
| 1 | Conservative Low-Strategists | 39.0 |
| 2 | Off-Farm Diversified Copers | 42.0 |
| 3 | Proactive Risk Managers | 19.0 |

## VIII. POLICY IMPLICATIONS AND TARGETING FRAMEWORK

THE TYPOLOGY YIELDS A SEGMENTATION-BASED TARGETING FRAMEWORK WITH CLEAR POLICY RELEVANCE.

First, for Institutionally Dependent & Infra-Constrained households, the binding constraint is not only exposure but the lack of enabling infrastructure and high transaction costs. Policy packages for this group should prioritize public investment in irrigation reliability, local storage and aggregation, and market connectivity. Alongside physical infrastructure, 'institutional infrastructure' matters: last-mile facilitation for scheme enrollment, grievance redress mechanisms, and predictable service delivery reduce the perceived institutional risk that dominates this group's risk environment.

Second, Conservative Low-Strategists benefit from capability-building interventions. This group is the natural target for strengthened extension systems, demonstration-based learning, and advisory services that simplify complex decisions. Importantly, extension for this group should be framed as risk-reducing—helping farmers adopt low-cost resilience measures, improve input timing, and use decision tools. In addition, linking this group to collective institutions (cooperatives, FPOs) can reduce transaction costs in marketing and input purchase.

Third, Off-Farm Diversified Copers demonstrate that diversification is already an organic response for many households. Policy should therefore focus on improving the quality and stability of diversification pathways—through skills development, local non-farm employment linkages, and support for rural micro-enterprises. This is relevant because diversification can reduce the covariance between farm income and household income, increasing resilience.

Fourth, Proactive Risk Managers are poised to benefit from more sophisticated instruments. For this group, the key policy issue is not adoption willingness but the availability and performance of products and services. Tailored credit products that recognize farm cash-flow cycles, transparent and timely crop insurance settlement, and digital advisory services can raise the productivity frontier. Importantly, leveraging this group as 'local innovators' in peer-learning networks can generate spillovers to other segments.

Across all segments, the typology supports a shift from scheme-centric implementation to portfolio-centric design. Instead of asking whether a scheme 'reached' farmers, the policy question should be whether households' risk-management portfolios improved: did they diversify risk, reduce exposure, and lower the need for distress coping? Segment-sensitive packages can be evaluated against this portfolio criterion.

Operationally, segmentation can be implemented without re-running PCA and clustering in every program cycle. Once the typology is established, a short diagnostic questionnaire can be developed using a small subset of high-discriminating items and a scoring rule that maps respondents into segments with acceptable accuracy. Extension staff or digital advisory platforms can use this diagnostic at enrollment or first contact to assign a household to a

segment. Programs can then deliver differentiated packages: for example, infrastructure-constrained households can be prioritized for community irrigation and storage interventions, while proactive households can be offered advanced credit-plus-advisory products. This 'lightweight' implementation strategy improves feasibility while preserving the conceptual value of the typology.

## IX. LIMITATIONS AND FUTURE RESEARCH

Two limitations should be noted. First, the typology is derived from cross-sectional survey evidence. While it captures heterogeneity at a point in time, households may transition across segments as constraints relax or as they experience new shocks. Second, perception measures are subjective and can be influenced by recent experiences. Future research can integrate administrative records (insurance participation, credit history) and panel outcomes (income variability) to validate and refine the typology.

Despite these limitations, the typology provides a practical diagnostic framework that is directly implementable: it identifies where constraints bind and provides a segmentation logic for targeting extension, infrastructure, and financial instruments.

## X. CONCLUSION

This paper develops data-driven farmer typologies for Haryana based on risk perceptions and risk-management portfolios. Using PCA-based clustering, it identifies three perception clusters and three strategy clusters and interprets them through a constraints-and-capabilities lens. The results argue against one-size-fits-all risk policies and support segment-sensitive packages that align infrastructure, advisory services, and financial instruments with farmer heterogeneity. The typology can help policymakers and implementing agencies prioritize investments and tailor delivery channels so that risk-management interventions translate into genuine resilience and sustained productive investment.

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