



Constructing an Actionability Evaluation Indicator System for Public Meteorological Services: A Protective Action Decision Model-Based Framework for Flue-Cured Tobacco Production in Liuyang

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Abstract. Public meteorological services in agriculture are increasingly expected to do more than release forecasts; they are also expected to help users turn warnings into timely protective action. Yet at county and grassroots levels, a persistent gap remains between receiving a warning and actually responding to it. Existing evaluation approaches usually center on forecast accuracy, user satisfaction, or economic benefit. While useful for assessing service supply or ex post outcomes, these approaches do not fully explain why some warnings fail to trigger disaster-prevention behavior even after they have been received. Building on the Protective Action Decision Model (PADM), this study develops an actionability evaluation framework organized around the sequence of warning reception, comprehension, assessment, and action, and operationalizes it in the context of flue-cured tobacco production in Liuyang, Hunan Province. The framework comprises four dimensions: Information Accessibility, Comprehension Reachability, Decision Usability, and Action Executability, covering 11 indicators in total. In this way, "actionability" is reframed from a general normative notion into a measurable and diagnosable process tool, offering a path for shifting public meteorological service evaluation from dissemination performance toward action performance.

Keywords: public meteorological services; actionability; PADM; warning-to-action conversion; evaluation indicator system; flue-cured tobacco

1 Introduction

Agricultural public meteorological services are moving from weather reporting toward action-oriented support. The 2015 WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services make clear that warning services should not stop at

describing meteorological phenomena, but should also help users interpret likely impacts and select suitable protective measures^[1]. The 2021 follow-up further stresses that impact-based warning principles need to be embedded in routine operational service delivery^[2]. In China, the Outline for High-Quality Development of Meteorology (2022-2035) calls for a modern meteorological system built on precise monitoring, accurate forecasting, refined services, and public satisfaction, thereby reaffirming meteorology as the first line of defense against disasters^[3]. Related arrangements for the new agricultural meteorological service system also call for hazard-specific, regionally differentiated, and time-sensitive warning systems, together with more targeted services for new agricultural business entities^[4]. Taken together, these policy signals suggest that public meteorological services should be judged not only by forecast precision or message reach, but also by whether the information can be converted into concrete action.

Even with major improvements in communication technology, a basic tension remains at the county production front line: warning channels are broader and coverage is higher, yet the step from receiving a warning to taking action is still often broken. Agricultural production responds sharply to weather changes, while disaster-prevention decisions are constrained by scattered plots, multiple production stages, narrow response windows, and losses that are often irreversible. For grassroots actors, receiving information is only the beginning. What matters more is whether risks can be judged in time, appropriate responses can be chosen, and organizational execution can be completed quickly enough to reduce damage.

Against this background, this study develops an actionability evaluation indicator system for public meteorological services from the perspective of warning-to-action conversion. Using flue-cured tobacco production in Liuyang, Hunan Province as the operational context, the study specifies indicator definitions, quantification rules, and data sources, and thus provides a workable framework for extending evaluation from dissemination performance to action performance.

2 An Actionability Analysis Framework from the PADM Perspective

2.1 Defining Actionability and the Applicability of PADM

In this study, "actionability" is treated neither as a synonym for forecast accuracy nor as a direct proxy for final loss reduction. Forecast accuracy reflects the technical performance of meteorological products, but even an accurate forecast may have weak actionability if users cannot interpret its impact information or cannot translate that understanding into a response. Final loss outcomes are also an incomplete substitute, because they are shaped by hazard intensity, resource conditions, actor capacity, and market circumstances. For this reason, actionability is better understood as a process attribute: whether the chain from warning release to action initiation remains connected and operable.

The Protective Action Decision Model (PADM) offers an appropriate theoretical basis for evaluating this process. Developed and refined by Lindell and Perry, PADM

has been widely used in studies of disaster warning response^[5]. Existing research shows that people do not move directly from warning receipt to action; instead, they typically pass through stages such as attention, comprehension, appraisal, deliberation, and decision-making^[6]. PADM therefore draws attention not only to whether information is received, but also to how risk is understood, how response options are assessed, and whether implementation conditions are available. These mechanisms closely match the practical problems encountered in agricultural meteorological services.

2.2 The Four-Dimensional Framework and Its Derivation Logic

To keep the dimensional structure clear and auditable, the derivation of dimensions follows three criteria: each dimension must correspond explicitly to a PADM stage, each must be expressible through observable indicators and feasible data sources, and the full set must preserve a sequential relationship so that the same attribute is not counted repeatedly under different labels. Following these criteria, the actionability of public meteorological services is organized into four core dimensions.

Information Accessibility corresponds to PADM's attention and reception stage in the pre-decisional process. The key issue here is whether a warning reaches the intended actors within the usable decision window and is actually noticed. If the message does not arrive in time, later steps such as comprehension, appraisal, and execution cannot meaningfully proceed.

Comprehension Reachability maps onto PADM's comprehension stage and the formation of risk perception. It asks whether a warning message can translate meteorological variables into production-relevant consequences so that recipients understand how changing weather may affect specific farming activities. Empirical studies underline the importance of this step. Weyrich et al. show that combining impact information with behavioral recommendations can improve public perception, comprehension, and intended responses to warnings^[7]. Potter et al., based on survey evidence from New Zealand, find that impact-based severe weather warnings reshape risk perceptions and intended protective actions^[8]. Lu et al. further report from a multimodal scenario simulation experiment that action instructions, available response time, and presentation mode all influence tendencies toward protective behavior^[9]. These findings suggest that content which is easy to understand and directly useful for judging action is critical to implementation effectiveness.

Decision Usability relates to PADM's evaluation of protective options within its core perceptual process. Once recipients understand the risk, the question becomes whether the warning provides enough basis for deciding whether to act, what should be prioritized, and what preparations are required.

Action Executability corresponds to response behavior and its enabling conditions in PADM. It examines whether an intended response can actually be carried out under real operating conditions. In agricultural settings, even when actors are willing to respond, action may still be delayed or blocked by the absence of standard procedures, unclear dispatch arrangements, weak organizational coordination, or incomplete records of what was done.

Taken together, the four dimensions form a stepwise chain: access to information makes comprehension possible, comprehension provides the basis for evaluating recommended measures, and even when an intention to act has formed, actual execution still depends on whether the necessary operating conditions are in place. The four-dimensional framework thus constitutes not a general description of public meteorological services, but a process-analytical tool capable of identifying conversion breakpoints and locating weak links.

3 Operationalizing the Framework in Liuyang Flue-Cured Tobacco Production

3.1 Operational Context and Design Principles

This study uses flue-cured tobacco production in Liuyang, Hunan Province as the operational context. This setting is suitable for framework operationalization because flue-cured tobacco production is highly sensitive to meteorological conditions, and disaster-prevention decisions are characterized by high time-sensitivity, high uncertainty, and high potential losses. Key production stages, including transplanting, field management, harvesting, and curing, are all susceptible to low temperatures and limited solar radiation, heavy rainfall, waterlogging, high-temperature drought, and severe convective weather, and losses from missing critical action windows are often irreversible. At the same time, the hilly and mountainous terrain of Liuyang gives rise to marked microclimatic variation, placing high demands on the spatial specificity of warnings. Local flue-cured tobacco production predominantly adopts a "cooperative plus household" organizational model, which means that warning responses entail both individual comprehension and judgment and organizational-level dispatch and coordination. Existing research demonstrates that flue-cured tobacco cultivation is highly sensitive to spatial variation in climatic factors such as temperature, precipitation, and sunshine duration, and that regionalization results based on refined meteorological variables can directly support the optimization of production area layout and production decision-making^[10].

3.2 The Four-Dimensional Indicator System

Based on the foregoing, this study operationalizes an actionability evaluation system for public meteorological services comprising 4 dimensions and 11 indicators, as presented in Table 1.

Table 1. Actionability Evaluation Indicator System for Public Meteorological Services.

Dimension	Code	Indicator	Type	Core Definition and Data Source
Information Accessibility	A1	Warning Reach Rate	C	Number of target actors who actually received the warning within the effective decision window / total number of target actors $\times 100\%$; data sources: SMS and WeChat platform delivery logs and target recipient roster.
	A2	Spatial Specificity	C	Number of warnings containing township- or grid-level location information / total number of warnings $\times 100\%$; data sources: warning texts and historical message archive.
	A3	Channel Redundancy	C	Number of warnings delivered through 2 or more independent channels / total number of warnings $\times 100\%$; data sources: SMS, WeChat, broadcast, and telephone records.
Comprehension Reachability	A4	Impact Clarity	C	5-point scale assessing whether the warning translates meteorological variables into production impacts; data sources: warning texts and scoring sheets.
	A5	Threshold and Window Specification	C	Number of warnings that both specify a trigger threshold or risk level and indicate the action deadline window / total number of warnings $\times 100\%$; data sources: warning templates and historical message archive.
	A6	Risk Level Readability	M	5-point scale assessing whether the risk level description is easy for target actors to understand; data sources: warning texts and comprehension tests.
Decision Usability	A7	Action Option Completeness	C	5-point scale assessing whether actionable recommendations, priorities, deadlines, and applicable actors are provided; data sources: action recommendation texts and scoring sheets.
	A8	Resource Visibility	C	5-point scale assessing whether action recommendations specify required resources and their acquisition channels; data sources: action recommendation texts and resource inventories.
Action Executability	A9	SOP Completeness	C	5-point scale assessing whether directly executable standard operating procedures exist; data sources: SOP documents, institutional records, and training materials.
	A10	Organizational Response Efficiency	C	Measured by time elapsed before the first action is initiated, normalized against the effective decision window; data sources: dispatch logs, work orders, and group check-in records.
	A11	Action Documentation Completeness	M	Number of "warning–action–acknowledgment" events with complete field entries / total number of events $\times 100\%$; data sources: event registration forms and acknowledgment records.

Note: C = Core indicator, applicable across contexts; M = Modular indicator, context-sensitive and replaceable in different application scenarios, provided consistency with the corresponding PADM construct is maintained. Source: Compiled by the authors based on PADM and the Liuyang flue-cured tobacco case.

The indicator system preserves a sequential diagnostic logic: A1-A3 assess whether warnings reach target actors in time and at an appropriate spatial scale; A4-A6 assess whether risk information can be understood and interpreted for production decisions; A7-A8 assess whether action options are specific enough to support choice; and A9-A11 assess whether intended responses can be executed and documented. This structure supports both stage-by-stage diagnosis and weak-link identification.

3.3 Scoring Methods and the Minimum Application Workflow

For application purposes, the indicators are divided into objective and subjective types. Objective indicators (A1, A2, A3, A5, A11) can be calculated directly from logs, texts, or administrative records. Subjective indicators (A4, A6, A7, A8, A9) adopt anchored scores of 1, 3, and 5, where 1 denotes absent or overly generic guidance, 3 denotes partial but incomplete guidance, and 5 denotes clear, actor-specific, and directly usable guidance. For A10, "Organizational Response Efficiency," the elapsed time before the first action is initiated is inversely normalized by the effective decision window so that more timely responses receive higher scores.

When a single warning event or a single severe weather episode is used as the basic evaluation unit, the following workflow is recommended. First, determine the effective time window and the scope of target actors for the event. Second, collect data for each indicator according to Table 1, calculating percentages directly for ratio-type indicators and averaging independently scored ratings from at least three raters for scale-type indicators. Third, convert all indicators to a standardized 0–100 scale to improve cross-indicator comparability. Finally, calculate scores for each dimension and an overall score, and identify the lowest-scoring dimension and its weakest indicator as the priority direction for service improvement.

From a diagnostic standpoint, if A1–A3 scores are relatively high while A4–A6 are low, the problem lies primarily in impact interpretation and risk expression rather than in dissemination coverage; if scores for the first three dimensions are adequate but A9–A11 are low, the bottleneck is more likely in organizational dispatch and execution mechanisms rather than in the warning product itself. Evaluation results can thus generate not only a composite score but also point to specific areas for improvement.

4 Conclusions

The theoretical contribution of this study lies first in transforming "actionability" from a normative concept into a measurable process-evaluation framework. Existing research on public meteorological services has predominantly focused on accuracy, satisfaction, and economic benefits as evaluation objects, namely indicators capable of reflecting service supply quality or post-hoc outcomes, but ill-suited to entering the

conversion process that unfolds "after a warning arrives." Using PADM as the sole theoretical anchor, this study derives four dimensions (Information Accessibility, Comprehension Reachability, Decision Usability, and Action Executability) and connects them to 11 indicators, thereby forming a complete chain from theory to dimensions, indicators, and criteria. This design shifts public meteorological service evaluation away from product quality and outcome attribution alone and toward process diagnosis and mechanism identification.

This study also places actionability between evaluations of service supply quality and evaluations of action performance. Accuracy evaluation asks whether forecasts are correct; satisfaction evaluation concerns how users perceive the service; and benefit evaluation asks whether loss reduction is achieved. Actionability evaluation, by contrast, focuses on why warnings do or do not translate into action. It is therefore not meant to replace existing evaluation approaches, but to complement them by providing a more precise basis for locating operational weaknesses.

In terms of practical significance, the system can provide county-level agricultural meteorological services with a low-threshold, replicable process-diagnostic tool. For operational uptake, the framework can be deployed in three simple forms: a one-page PDF checklist for post-event review, an Excel-based scoring sheet for county service managers, and, where available, a platform-based dashboard. Its main users include warning issuance staff, agricultural extension personnel, tobacco cooperative managers, township emergency liaisons, and communication operators involved in dissemination. The assessment should be completed within 24-48 hours after a major warning event and incorporated into seasonal review, SOP updating, and staff training. These operational arrangements depend on sustained coordination among meteorological bureaus, tobacco service stations, cooperatives, township governments, and communication providers, each contributing distinct capabilities to the warning-to-action chain.

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