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Socioeconomic Impact of Modern Biotechnology Seed Development in Indonesia : A Case Study of GM Maize Seed

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Why Study GM Maize Seed?

Rising demand meets scarcer resources, so productivity must rise through better technology

1

Demand keeps rising

Feed, food industry and other uses of maize

2

Resources get scarcer

Land, water and farm labor

3

Efficiency must improve

Adaptive technology; seed is a key component

Why GM (PRG) seed?

- Fewer young people want to farm, so farm labor is scarce and farm machinery and herbicide use is essential, including in maize
- GM maize seed offers high tolerance to glyphosate herbicide

After more than five years of farm-level use, the impacts of GM maize seed need to be assessed beyond productivity

72,21%

of maize farmers use hybrid seed (BPS, 2025)

62,7%

of maize production is used for animal feed (Alta et al., 2025)

206.3 million ha

area planted with modern biotechnology crops in 27 countries (2023)

Are the reported benefits realized on actual farms, by whom, and under what institutional conditions?

Research Objectives and Method

Four objectives

1

Analyze farm-level benefits of GM maize seed

2

Analyze technical and economic efficiency

3

Analyze social impacts at farm level

4

Formulate a policy strategy for GM maize seed in Indonesia

Method

Mixed methods: primary farm survey plus FGDs with seed supply chain stakeholders

Comparable groups: GM and non-GM farmers from the same or adjacent sub-districts, to minimize socio-cultural, institutional and agro-ecosystem differences

Coverage: Java and outside Java; simple random sampling within each group

Analysis: descriptive statistics, NVivo qualitative analysis, econometrics

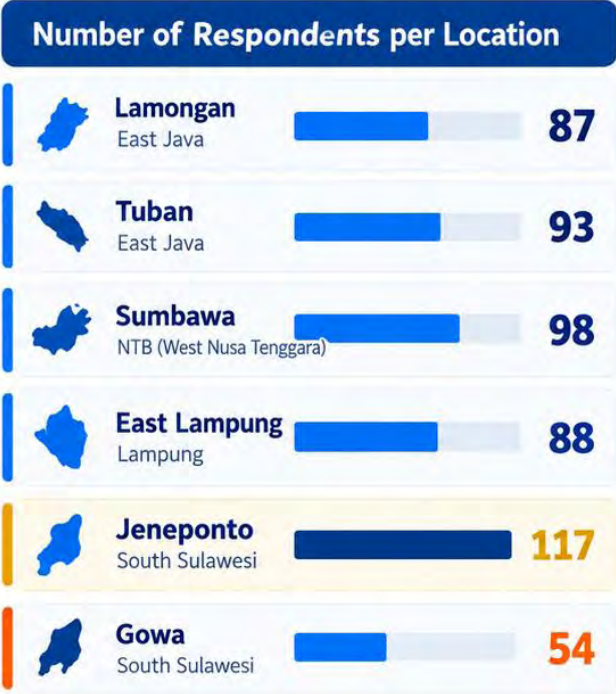
Each objective is addressed using specific data and methods, then integrated during interpretation and strategy formulation

Objective	Data	Analytical methods	Output
1. Benefits	Production, inputs, costs, profits, perceptions	Descriptive statistics, farm analysis (R/C), NVivo	GM vs non-GM performance comparison
2. Efficiency	Production per ha, inputs, farm characteristics	Cobb–Douglas SFA (technical efficiency, inefficiency factors); economic efficiency limited to R/C	Technical efficiency scores; financial performance
3. Social impacts	Interviews, FGDs, observation	NVivo thematic analysis, triangulation	Social impacts and mechanisms
4. Strategy	Synthesis of objectives 1–3; GM farmers' perceptions	MIPA: IPA_AGRO and IPA_SOSEK (CFA, 12 indicators, scale 1–10)	Policy intervention priorities

Allocative efficiency was not estimated: variation in input prices in the single-period survey was too limited. Perception findings are reported as perceptions, not objective measures.

LOCATION AND DISTRIBUTION OF RESPONDENTS

Socio-Economic Study on the Use of GM Maize Seeds | **Total of 537 respondents**



Composition of Respondents



GM seed users are maize farmers with primary–secondary education; adoption is shaped by retailers, extension services, financing, and evidence from other farmers

450 farmers

241 GM · 209 non-GM; 827 farm observations

80,9%

of GM farmers: maize is their main occupation (non-GM: 79.4%)

78,8–84,5%

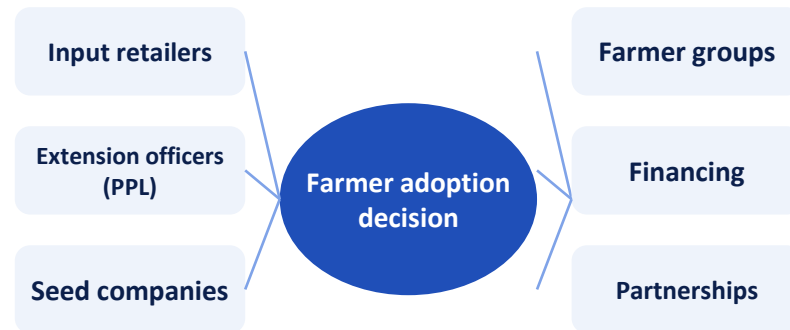
of GM seed obtained through agricultural input retailers

95–98%

of GM users have adopted it only within the past 1–3 years

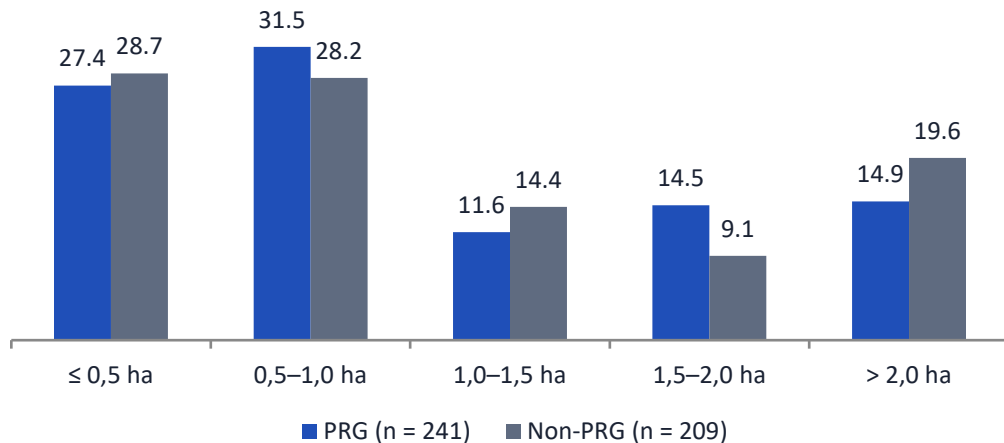
GM users	Java	Outside Java
Age over 65	20.0%	6.2%
Primary education or less	51.3%	32.9%
Initial information from extension officers	46.3%	32.3%
Initial information from seed sellers	35.0%	21.7%
Main financing method	Formal KUR loans	Pay at harvest (informal)

Adoption ecosystem



Most Cultivating Farmers Are Smallholders

Distribution of farmers by total cultivated area (% of farmers)



85,1%

of GM farmers cultivate ≤ 2 ha (non-GM: 80.4%)

58,9%

of GM farmers cultivate ≤ 1 ha (non-GM: 56.9%)

GM farmers	≤ 1 ha	≤ 2 ha
Java	77.5%	97.5%
Outside Java	49.7%	78.9%

As most cultivating farmers are smallholders (85% of GM farmers cultivate ≤2 ha), GM seed development could strengthen smallholder competitiveness through 4.6% higher production and 17.3% lower farm costs, provided seed access is equitable and products continue to improve.

Input use and production per hectare: GM vs non-GM maize

GM maize farms use less seed and far less herbicide, with slightly higher yield

Production input	GM maize (n=440)		Non-GM maize (n=387)	
	Mean	c.var*	Mean	c.var*
Seed (kg)	14.66	0.16	18.50	0.16
Urea fertiliser (kg)	338.33	0.21	331.37	0.21
NPK fertiliser (kg)	206.41	0.19	209.68	0.19
Organic fertiliser (Rp '000)	154.51	1.64	158.09	1.49
Herbicide (Rp '000)	734.65	0.24	1,443.98	0.44
Pesticide (Rp '000)	399.52	0.69	435.38	0.65
Other inputs (Rp '000)	347.00	1.24	382.68	0.94
Labour (person-days)				
Family labour	13.11	0.69	9.75	0.74
Hired labour	8.90	0.35	11.89	0.49
Total labour	22.00	0.51	21.64	0.30
Production (quintal, dry shelled)	71.31	0.15	68.16	0.18

-21% **Seed use**
14.66 vs 18.50 kg/ha

-49% **Herbicide cost**
Rp 735k vs Rp 1,444k/ha

+4.6% **Production**
71.31 vs 68.16 quintal/ha

*c.var = coefficient of variation. Percentages are GM relative to non-GM means. Data: 2026.

Input use and production by region: Java vs outside Java

Herbicide savings of about 47–52% hold in both regions; the yield gain is larger outside Java (+7.7% vs +1.3%)

Production input	GM maize farms				Non-GM maize farms			
	Java		Outside Java		Java		Outside Java	
	Mean	c.var*	Mean	c.var*	Mean	c.var*	Mean	c.var*
Seed (kg)	14.88	0.18	14.54	0.15	18.54	0.14	18.47	0.18
Urea fertiliser (kg)	349.92	0.21	331.70	0.21	343.81	0.18	322.79	0.22
NPK fertiliser (kg)	214.36	0.17	201.86	0.20	220.01	0.17	202.55	0.21
Organic fertiliser (Rp '000)	244.05	1.39	103.35	1.61	241.30	1.38	100.68	1.01
Herbicide (Rp '000)	779.09	0.20	709.26	0.26	1,606.50	0.47	1,331.85	0.39
Pesticide (Rp '000)	527.80	0.56	326.22	0.71	510.52	0.60	383.55	0.66
Other inputs (Rp '000)	585.03	0.95	210.99	1.20	573.19	0.80	251.24	0.70
Labour (person-days)								
Family labour	19.86	0.48	9.25	0.62	15.21	0.61	12.88	0.58
Hired labour	10.39	0.40	8.05	0.24	17.45	0.80	14.96	0.21
Total labour	30.25	0.44	17.29	0.34	32.66	0.25	27.84	0.31
Production (quintal, dry shelled)	74.06	0.13	69.74	0.15	73.12	0.16	64.73	0.17

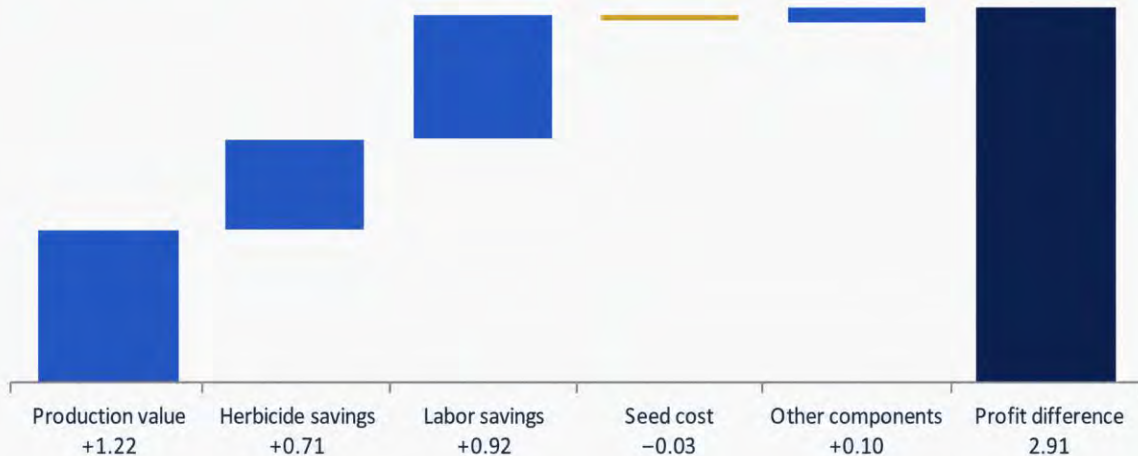
*c.var = coefficient of variation. Shaded columns = GM maize. Percentages are GM relative to non-GM means. Data: 2026.

The added value of GM seed use is reflected in productivity and a more efficient cost structure

Analysis aspect	Maize Farming in Java		Maize Farming Outside Java	
	GM	Non-GM	GM	Non-GM
Average revenue	Rp30.57 million/ha	Rp30.08 million/ha	Rp27.78 million/ha	Rp25.85 million/ha
Revenue stability	Lower variation → more stable and consistent revenue	Higher variation	Lower variation → more stable farming performance	Higher variation
Total production costs	Rp9.19 million/ha	Rp10.22 million/ha	Rp7.48 million/ha	Rp9.51 million/ha
Herbicide costs	Rp779 thousand/ha	Rp1.61 million/ha	Rp709 thousand/ha	Rp1.33 million/ha
Labor costs	Rp3.03 million/ha	Rp3.26 million/ha	Rp2.16 million/ha	Rp3.48 million/ha
Labor stability	More stable and uniform	Higher variation	More efficient and stable	Higher variation
Average profit	Rp21.38 million/ha	Rp19.87 million/ha	Rp20.29 million/ha	Rp16.34 million/ha
R/C ratio	3.49	3.01	3.8	2.79

GM profits are Rp2.91 million/ha higher; about 58% of the difference comes from cost savings, not selling prices

Decomposition of the Profit Difference between PRG and Non-PRG (IDR million/ha)



+4,6%

production: 71.3 vs 68.2 quintals/ha

-49%

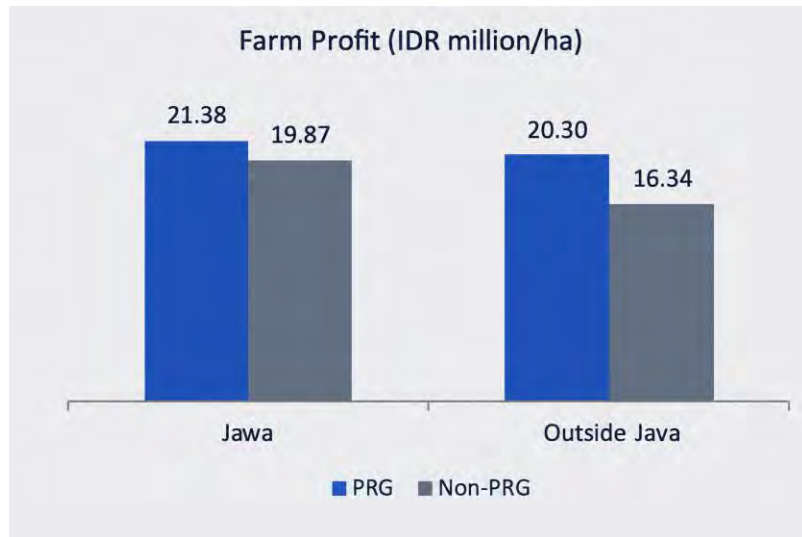
herbicide costs: Rp0.73 vs 1.44 million/ha

+16,4%

profit: Rp20.69 vs 17.78 million/ha; R/C
3.69 vs 2.88

*Implicit prices are nearly identical ($\pm$ Rp4,040/kg):
no price premium.*

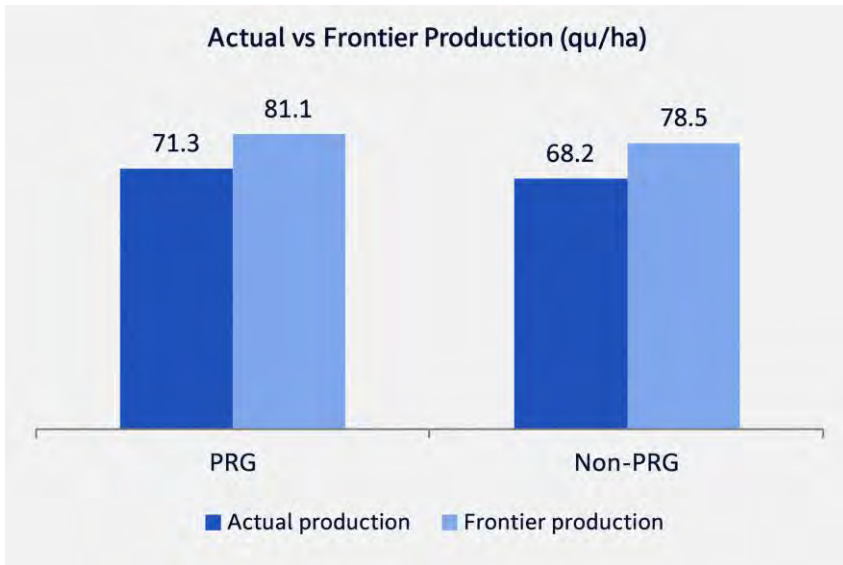
The financial advantage of GM maize holds both in Java and outside Java, but its sources differ: cost efficiency in Java, and output and labor outside Java



GM vs non-GM	Java	Outside Java
Profit difference	+7.6%	+24.2%
R/C	3.49 vs 3.01	3.80 vs 2.79
Production (quintals/ha)	74.1 vs 73.1	69.7 vs 64.7
Labor costs	-7%	-38%
Herbicide costs	-52%	-47%
Cost savings contribution	≈68%	≈51%

GM vs non-GM cost structure: herbicides 9.1% vs 14.7% · labor 30.5% vs 34.6% · seed 26.9% vs 21.9%

Both groups show high technical efficiency (0.87 vs 0.86); the difference is small, with a remaining gap of ± 10 quintals/ha to the frontier

**0,874**

GM technical efficiency

0,863

Non-GM technical efficiency

Technical efficiency is not productivity

Technical efficiency = actual output $\div$ maximum output with the same inputs (0–1 scale).

Productivity = yield per hectare.

GM yield elasticity with respect to herbicide approaches zero: additional output does not depend on additional herbicide.

Seed trait: uniform growth



Farming practice: less frequent spraying

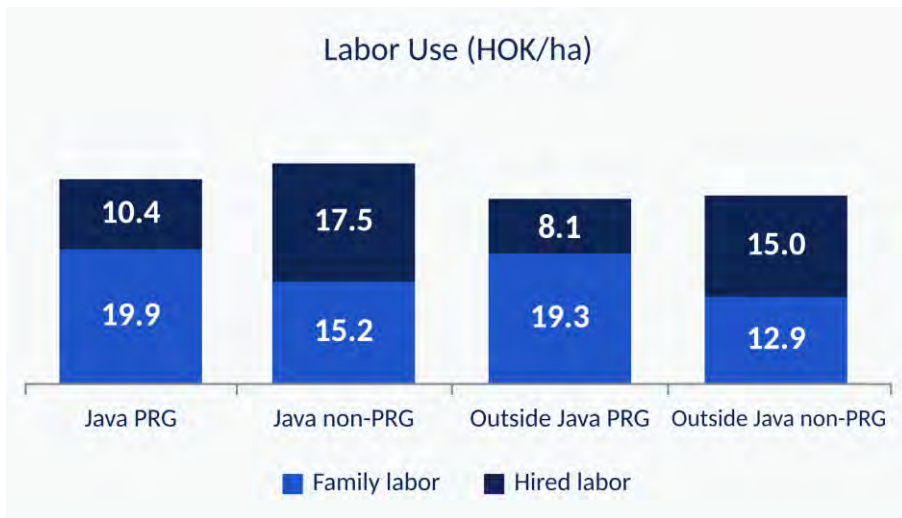


Input use: herbicides, labor



Yields and efficiency

Labor savings are the most measurable social impact: they benefit farmers but reduce paid labor days



Stakeholder	Measured	Qualitative indications
User farmers	Lower herbicide and labor costs	Easier farm planning
Families, women	Family working hours vary	Time shifts to livestock, small trading
Farmworkers	Hired labor decreases by ± 7 workdays/ha	Less seasonal work; worker voices not yet captured
Farmer groups, extension officers	—	Peer learning and word of mouth

“Work now gets done faster, so women can help oversee harvesting and tend side plots, look after livestock, or run small businesses.” — Farmer interview

Seed access, informal financing, and dependence on a single distribution channel determine who receives and retains the benefits

1

Access

Agricultural input retailers distribute 78.8–84.5% of GM seed; supply and payment terms depend on one channel.

2

Information

Extension officers and seed sellers are the main sources; risk of bias arises if commercial actors dominate.

3

Financing

KUR in East Java and pay-at-harvest (yarnen) in Lampung, West Nusa Tenggara, and South Sulawesi can limit seed choices.

4

Perceived benefits

Users express uncertainty: “not always more profitable” (30.8% in Java; 57.9% outside Java).

Reasons former users stopped planting

56,3%

Java: difficulty obtaining seed

55,1%

Outside Java: cost factors

Identified risks

- Dependence on glyphosate and weed resistance
- Farmers with limited capital delay adoption because of higher upfront costs
- Perception that “seed is easy to obtain” (80–85%) comes from users: selection bias

Two opportunities exist: retaining users (87% intend to continue) and converting non-user interest ($\approx 49\%$), but intention is not adoption

Stage (distinct definitions)	Java	Outside Java
Has heard of GM seed (non-GM)	78.5%	59.2%
Has never planted it (non-GM)	53.1%	77.2%
Willing to try if other farmers succeed	41.8%	55.7%
Likelihood of trying (model)	44.3%	51.2%
Intention to continue, users (survey)	83.8%	90.1%
Intention to continue, users (model)	83.8%	89.3%

Overall: intention to continue 87.3% · likelihood of trying 48.5%

Product opportunities: current advantages rest on one trait (glyphosate tolerance), and non-GM competitors are emerging; move toward multiple traits: downy mildew, stalk rot, and drought resistance.

Seed access × adoption matrix

Low access · high adoption
West Nusa Tenggara:
strengthen distribution

High access · high adoption
Java, South Sulawesi:
maintain quality; learning
hub

Low access · low adoption
None identified

High access · low adoption
Lampung: evidence and
trust

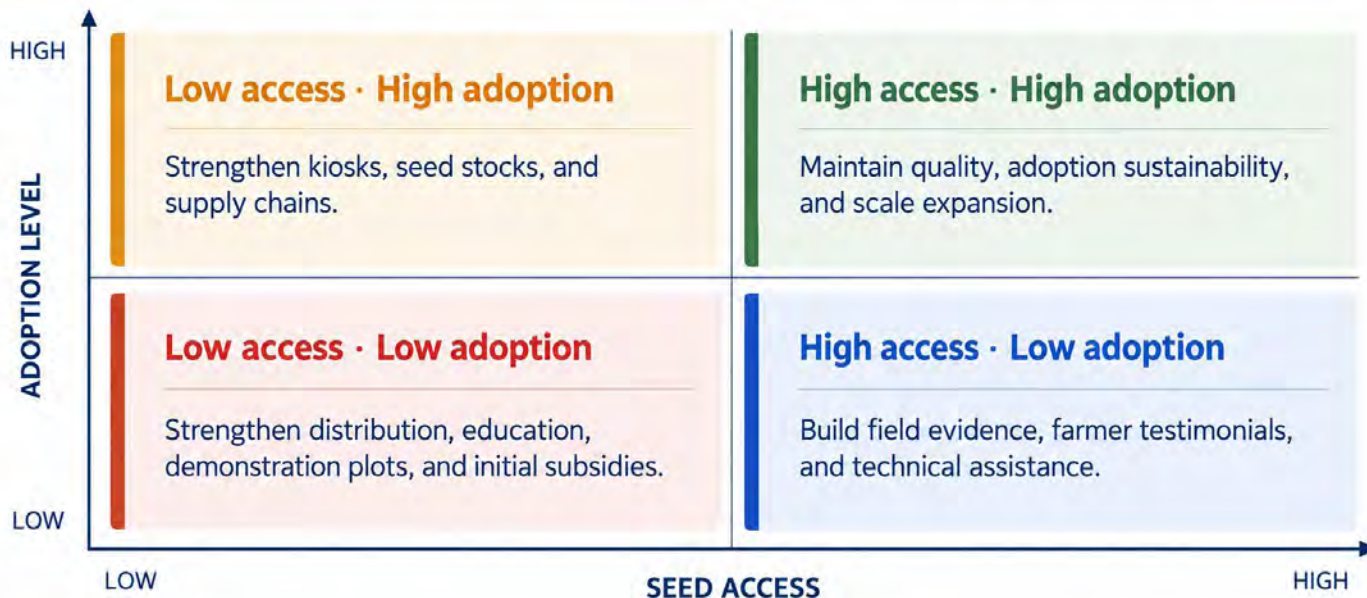
Likelihood of Non-GM Farmers Trying GM Seed (Based on Farmers' Perceptions)

Region	Variable	Mean	Std. Dev.	Coeff. Var.
Java and outside Java	Unwilling to use	0.223	0.172	0.774
	Undecided/don't know	0.292	0.205	0.703
	Willing to try	0.485	0.199	0.409
Java	Will not continue	0.380	0.132	0.348
	Undecided/don't know	0.177	0.127	0.719
	Willing to try	0.443	0.183	0.412
Outside Java	Unwilling to use	0.122	0.108	0.882
	Undecided/don't know	0.366	0.212	0.580
	Willing to try	0.512	0.205	0.399

Why might adoption opportunities be relatively greater in rural areas outside Java?

This may relate to three factors: (1) relatively scarcer labor in rural areas outside Java; (2) GM maize tolerance to glyphosate herbicide; and (3) food-crop farming technologies, including maize, being relatively less advanced and established than in Java.

GM Seed Access and Adoption Matrix for Setting Regional Intervention Priorities



GM maize seed adoption is influenced by technology characteristics and farmers' access to seed. Development strategies should therefore be adapted to local conditions based on combinations of seed access and technology adoption. This matrix groups regions into four types to determine appropriate intervention priorities.

Policy must operate on both sides: sustaining established demand and building supply so that access does not become a barrier

A. DEMAND SIDE

1. Retain existing users: quality assurance, after-sales service, extension support
2. Turn interest into trials: demonstration plots, lead farmers, verified testimonials
3. Prevent commoditization: education on total costs and multiple traits
4. Connect with the feed industry: quality-standard-based contracts

B. SUPPLY SIDE

1. Strengthen availability outside Java: retailers, logistics, stocks for peak planting
2. Shorten and formalize the chain: KUR credit, company–farmer group partnerships
3. Regulatory certainty and dissemination of standards to local governments
4. Evidence-based guidance: plot management and herbicide doses

Java: maintain quality; become learning hubs

Outside of Java: improve seed distribution

Outside Java : field evidence and trust

Safeguards for inclusion: transparent credit terms · farmer group bargaining power · farmworker training and job diversification · herbicide stewardship

Sustainable development requires verified benefits, more equitable access, farmer protection, and product innovation across three horizons

0–2 YEARS

Expand access

Priorities

- Expand retailers and formal financing outside Java
- Disseminate standards and establish demonstration plots (high access–low adoption)
- Maintain quality and after-sales service

Actors

Seed companies, retailers, banks, local governments, extension officers

Proposed indicators

Retailer coverage; peak-season stocks; KUR access; number of demonstration plots; intention to continue

3–5 YEARS

Build institutions

Priorities

- Quality-based off-taker partnerships
- Update GM and genome-editing regulations
- Efficient distribution, farmer group partnerships, extension support

Actors

Ministries, feed industry, seed companies, farmer groups

Proposed indicators

Number of quality contracts; revision status of Government Regulation 21/2005; distribution efficiency

> 5 YEARS

Sustain competitiveness

Priorities

- R&D on multiple traits (downy mildew, stalk rot, drought)
- R&D–company–government networks
- Evaluate economic and social impacts

Actors

R&D institutions, seed companies, government

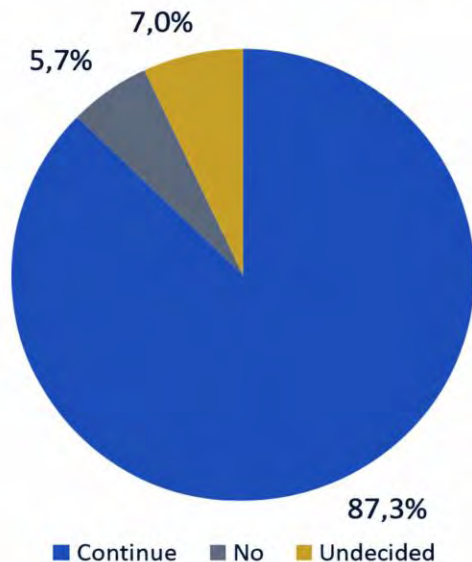
Proposed indicators

Release of multi-trait varieties; monitoring of impacts (costs, farmworker days)

Verified benefits · equitable access · farmer protection · robust agribusiness ecosystem · sustainable product innovation

GM benefits are demonstrated at farm level: higher output and lower costs, not higher prices, and 87% of users intend to continue

Intention to Continue Using PRG (% of users)



+16,4%

profit: Rp20.69 vs 17.78 million/ha

+4,6%

production: 71.3 vs 68.2 quintals/ha
(statistically significant)

-49%

herbicide costs: Rp0.73 vs 1.44 million/ha

≈0,87 vs 0,86

GM vs non-GM technical efficiency:
small difference

- Sources of benefits: higher output and lower costs; markets do not differentiate selling prices
- Similar patterns in Java and outside Java
- Agronomic advantages rated positively by 72.5–95.0% of respondents

Further adoption depends on access, trust, social impacts, and seed competitiveness amid glyphosate-tolerant non-GM competitors

1 Access and institutions

Input retailers account for 78.8% (Java) and 84.5% (outside Java) of seed access. KUR is more developed in Java; pay-at-harvest financing affects sustainability outside Java.

2 Trust and opportunities

Likelihood that non-GM farmers will try GM seed: 0.49 (Java 0.44; outside Java 0.51), affected by region, age, and number of plots. Agronomic and socioeconomic assessments move together: demonstration evidence matters.

3 Social impacts

Labor savings help labor-constrained households but reduce paid farmworker days, particularly for women. Access disparities and ecological impacts have not yet been monitored.

4 Seed competitiveness

The advantage rests on one trait (glyphosate tolerance). Similar non-GM competitors, higher seed prices, and alternative weed control could narrow that advantage.

Implication: the priority shifts from proving benefits toward improving supply and access, building trust, and maintaining competitiveness.

Recommendation: shift from proving benefits to improving supply, building trust, and sustaining competitiveness

1

New policy focus

Supply and access, trust in low-adoption areas, and seed price competitiveness.

2

Region-specific strategies

Distribution, extension, business partnerships, and field evidence of benefits.

3

Outreach and regulation

Facilitate communication about benefits and impacts; update GM and genome-editing regulations.

4

Technical efficiency opportunities

Networks to ensure seed availability for biotic stress, abiotic stress, and climate change.

5

Outreach to local governments

Short, accessible messages; engage influencers and social media.

CropLife and its members

Promote multi-trait GM seed with BRIN and R&D networks: stalk rot, downy mildew, and climate stress.

BRIN and the Ministry of Agriculture

Regularly monitor equity of access (who is left behind) and long-term ecological impacts.

Farmers' Perspectives on GM Maize Seeds: Production Efficiency and Value Proposition

Technical Efficiency and Production Frontier of Maize Farming

"After using GM crops, field operations feel easier, and the results are more consistent."



Value Proposition of Genetically Monitored (GM) Maize Seeds

"Although GM seeds are more expensive, they remain profitable due to lower costs and reduced harvest risks."



THANK YOU
