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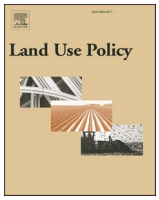

How institutional rule erosion shapes land use trajectories at forest margins in upland Indonesia

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ABSTRACT

Maladaptive land use change at forest margins presents a persistent governance challenge under climate and policy pressures. This paper introduces the concept of rule erosion to explain how the gradual and uneven weakening of institutional rules drives land use change. While institutional analyses have treated rule change as adaptive flexibility or as macro-level drift, the cumulative weakening of operational rules-in-use at the community level remains under-theorised. Drawing on the Upland Saddang watershed, Indonesia, we examine how the weakening of boundary, scope and payoff rules within multi-level governance has shaped farmers' decisions and narrowed adaptation pathways. The two study villages were selected from those in the watershed that were identified as experiencing persistent drought. In the two villages data was gathered from 35 farmer interviews covering 129 land plots, 10 stakeholder interviews, focus group discussions and participatory GIS. Using the Institutional Analysis and Development (IAD) framework, these findings show that maize cultivation (62.6% of plots) has become the dominant outcome across a wide range of former land uses—converting from paddy, cocoa, forest and grasslands—a pattern closely linked to repeated cycles of maize seed assistance rather than autonomous adaptation. Weakened boundary rules made maize seed assistance effectively open-access; loose scope rules have pushed it onto steep slopes and forest margins; and payoff rules have favoured short-cycle returns, narrowing available options and creating the conditions for what we term assistance-led maladaptation. The analysis extends the concept of erosion from constitutional and international-norms scholarship to community-level resource governance and calls for graduated multi-level safeguards that preserve local adaptive flexibility.

1. Introduction

Formal and informal institutional arrangements shape land use decisions through laws, regulations and social norms, with past rules shaping present land use (North, 1991, 1995). In practice, these arrangements operate as rules-in-use that structure who participates, which actions are permitted and how costs and benefits are distributed (Ostrom, 1990, 2005). However, the practices and incentives operating within these arrangements can shift relatively quickly with the introduction of new agricultural programmes and financial incentives (Hamilton-Hart, 2019; Fahira et al., 2022; Syahruddin et al., 2020;), producing unexpected and sometimes maladaptive outcomes (Müller et al., 2017; Dobler-Morales et al., 2021).

In this paper, we introduce the concept of rule erosion to explain how institutional arrangements have shaped land use decisions during the expansion of maize[3] seed assistance into upland areas and forest margins. This analysis draws on the Institutional Analysis and Development (IAD) framework and Historical Institutionalism, which examine how established practices and policy paths shape institutional change over time (North, 1995; Ostrom, 2005). We define rule erosion as the gradual weakening of these rules–especially boundary, scope and payoff–-through repeated programme cycles and shifting institutional priorities that gradually alter how policies operate in practice.

Yet existing work leaves an important gap. Institutional analyses tend to treat rule change as either adaptive flexibility (Ostrom, 2005; Quinn et al., 2007) or as macro-level drift in formal policy (Streeck and Thelen, 2005). Maladaptation studies explain harmful adaptation outcomes through policy failure or mis-implementation (Müller et al., 2017;

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[3] In this paper, 'maize' refers specifically to feed maize cultivated for livestock and 'local maize' refers to maize for households consumption.

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Biella et al., 2024), without linking them to the gradual weakening of operational rules-in-use. The concept of erosion has developed in law and constitutional settings (Bogojević, 2019; Lemke, 2014; Xu, 2025) and in international norms (Price, 2021), where it describes how rules lose their effective force through gradual and cumulative weakening. This framing has not been applied to community-level resource governance. This paper addresses that gap by introducing rule erosion to the IAD framework, showing how the asymmetric weakening of boundary, scope and payoff rules—often mistaken for flexibility—can channel land use decisions toward maladaptive outcomes.

The upland Saddang watershed in South Sulawesi, Indonesia, where there has been national concern about recent agricultural and social change, provides a useful empirical setting to explore rule erosion in practice and why it matters. The area is characterised by steep slopes and a long history of droughts that repeatedly disrupt farming livelihoods (Busthanul et al., 2020; Hatta and Yuni, 2019), rapid land use change and the conversion of steep slopes using agricultural techniques that accelerate soil erosion and forest loss (Asmira and Lias,; Rijal et al., 2021; Utami A et al., 2025). These conditions have made it a national priority to rehabilitate watersheds and restore forests (Mukti et al., 2025; Naufal et al., 2023).

Despite the availability of perennial, agroforestry and food-crop alternatives, maize cultivation has spread onto steep uplands, ridge tops and forest margins, a puzzle that this analysis seeks to explain through institutional dynamics. This shift exemplifies maladaptive land use trajectories, in which land use changes increase vulnerability over time by narrowing the options available to farmers and locking in practices that erode ecological and livelihood resilience.

In this paper, we ask how institutional arrangements shape land use change in the upper Saddang watershed under climate stress and whether the cumulative weakening of rules-in-use through repeated agricultural assistance can be characterised as rule erosion. Drawing on rules-in-use as the analytical lens (Ostrom, 2005), we trace how boundary, scope and payoff rules condition farmers' decisions when assistance programmes interact with climate pressure and multi-level governance.

The following sections develop this argument by first revisiting how rules-in-use have been treated in environmental governance and then by situating the case within Indonesia's agricultural food-security and forestry policies.

1.1. Rules-in-use in environmental governance

Ostrom introduced the concept of rules-in-use to explain how institutions shape behaviour in environmental governance (Ostrom, 2005; Ostrom et al., 1994). Rather than focusing on formal regulations or written policies, rules-in-use show how rules that actually structure everyday interactions (Ostrom, 1990, 2005). These rules form the analytical core of the IAD framework, which distinguishes boundary, position, choice, aggregation, information, payoff and scope rules as key components shaping behaviour within an action arena (Ostrom, 2005; Ostrom et al., 1994).

Several studies in Institutional settings treat rules-in-use as changeable rather than fixed (Adhikari and Lovett, 2006; Quinn et al., 2007; Whaley, 2018). Change occurs over time through the interaction of programmes, incentives, environmental pressures and local practices (Cash et al., 2006; Ostrom, 2009). Rules function effectively when participants understand them and can be reinforced in practices that align with the incentives actors face (Ostrom, 1990, 2005). Further studies also show that these institutional arrangements vary across communities and reflect local conditions rather than a uniform or perceived optimal design (Byerlee and Rueda, 2015; Dobler-Morales et al., 2021; Nagendra and Ostrom, 2012; Oberlack et al., 2018; Ostrom, 2007)

Local rules in communities can be dynamically adjusted adaptively, but conflicting sectoral policies and multi-level governance can make compliance unclear (Ching and Mukherjee, 2015; Cortner et al., 2024; Widiyanto et al., 2025; Young, 2002). In these situations, formal policy rules do not match how rules are applied on the ground, resulting in participation becoming harder to manage, coordination weaker and incentive structures less clear (Mack et al., 2019; Ostrom, 2005; Young, 2002). These institutional rules may persist on paper while becoming weakened in everyday decision-making over time (Streeck and Thelen, 2005).

Furthermore, institutional economics can also help explain rule erosion by focusing on transaction cost dynamics, particularly how changes in rules and actor behaviour interact (North, 1991, 1995). Rules that require detailed verification, monitoring or coordination tend to remain limited in reach as the costs of implementation constrain expansion (North, 1991, 1995; Mack et al., 2019). In contrast, programmes with low verification and monitoring requirements can spread rapidly across participants by reducing administrative burdens and increasing local flexibility (North, 1991, 1995; Mack et al., 2019). In this case, changes in rules can be interpreted as increased flexibility because they lower transaction costs (North, 1991, 1995).

However, in Saddang, these changes have narrowed rather than expanded farmers' options– a conceptual gap this paper addresses by introducing the mechanism of rule erosion within the IAD framework. This weakening has rarely been theorised as a distinct mechanism. Rule loosening is interpreted as adaptive flexibility, with limited attention to whether it can, in fact, narrow the practical set of options to actors, or how repeated external incentives can weaken some rule types while leaving others intact or lock in, appearing on the surface as flexibility.

1.2. Agricultural and food security governance in rural Indonesia

Historical institutionalism views policy change as a gradual process, in which existing priorities and implementation practices continue and are reshaped over time (North, 1991, 1995). In Indonesia, one of the key aspects of land and agricultural governance was reshaped following the post-Reformasi period (post−1998 Indonesian reform following the fall of Suharto's regime) when significant political and institutional restructuring occurred, as national concerns over food security and rural development became embedded in legislation, ministerial regulations and planning frameworks across government levels (Natadireja et al., 2024; Rusastra et al., 2016; Winoto and Siregar, 2008). These policy trajectories provide background for how agricultural land and forest support has been organised under successive presidential administrations (Amaruzaman et al., 2023; Timmer, 2018).

During the Susilo Bambang Yudhoyono (SBY) (2004–2014), maize was addressed within national food security and agricultural frameworks without being treated as a separate policy priority (Fahira et al., 2022; Tjondronegoro, 2013). In particular, the Ministry of Agriculture Regulation No. 15/2010 articulated targets for national maize self-sufficiency and outlined strategies centred on seed systems, fertiliser provision, and farmer training (Ministry of Agriculture, 2010). Presidential Instructions No. 5/2008 and No. 1/2010 also positioned food security as a national agenda without explicitly prioritising maize as broader national directives (Fahira et al., 2022; Tjondronegoro, 2013). The SBY period is associated with spatially differentiated interventions, including the development of production centres as hubs, storage facilities and large-scale estate initiatives (e.g., the Merauke Integrated Food and Energy Estate) (Fahira et al., 2022; Neilson and Arifin, 2012). Within this policy landscape, maize cultivation was incorporated into broader agricultural and estate-based strategies.

Two additional policy instruments further influenced the agricultural landscape of this period. Law No. 18/2012 on Food established a legal framework for food sovereignty, self-sufficiency and security by regulating production, trade and sale within a macro context (Neilson and Wright, 2017; Soetoto, 2018). Ministry of Agriculture Regulation No. 15/2013 on Food Diversification and Security promoted dietary diversification and strengthening of local food systems through

initiatives such as community food barns and local distribution mechanisms. In this context, maize was treated as one component within a broader set of agricultural interventions, often targeted toward selected locations and distribution systems (Neilson and Wright, 2017).

A more explicit and sustained national emphasis on maize emerged under President Joko Widodo (2014–2024). Food self-sufficiency strategies in this period increasingly named maize alongside rice and soybeans as priority crops, signalling a narrowing of national production focus (Dzulhidany and Rahman, 2022; Syahruddin et al., 2020). The Upaya Khusus Padi, Jagung dan Kedelai (UPSUS PAJALE; Special Effort Paddy, Maize and Soya bean) programme is frequently described as a central policy instrument or flagship of this period, characterised by accelerated implementation, input provision and coordination across multiple levels of government (Dzulhidany and Rahman, 2022; Prastiwi, 2016). Compared to earlier approaches, this period marked a stronger alignment between national production targets and programme delivery mechanisms.

Over the past decade, the upland Saddang watershed has been exposed to overlapping agricultural assistance schemes, food security programmes, Hutan Kemasyarakatan (HKm; social forestry) regulations, Non-Government Organisation (NGOs) initiatives (e.g., agroforestry and livelihood programmes) and Village Fund policy incentives (Busthanul et al., 2020; Yusriadi et al., 2024). These interventions originate from multiple governance levels and interact with climate pressure, market incentives and crop systems (Naufal et al., 2023).

This agricultural reorientation was supported by major institutional changes in rural governance following the enactment of the Village Law (Law No. 6/2014) (Ilhami, 2022; Supranata and Martiningsih, 2025). By expanding fiscal transfer to villages and formalising village-level development planning, the law integrated villages more directly into national development strategies. This expansion was operationalised through the Village Funds, which became an important channel for financing local priorities, particularly basic infrastructure such as rural roads, which featured prominently in village development agendas (Busthanul et al., 2020; Indraningsih et al., 2021). In response to COVID−19, villages refocused their budgets, with food security emerging as a key priority shaping Village Fund allocation (Akbar et al., 2024; Nurhidayah and Djalante, 2022). At the national level, this period also coincided with a decline in maize imports, due to a significant increase in domestic maize production under the Jokowi administration (Hamilton-Hart, 2019; Syahruddin et al., 2020).

2. Methods

2.1. Village selection

This study examines institutional arrangements under climate stress, with an initial analysis conducted prior to fieldwork to guide village selection; village selection was based on evidence of persistent drought, ensuring that the institutional dynamics analysed were situated within clear climatic pressure. Ground station data from the Badan Meteorologi, Klimatologi dan Geofisika (BMKG; Indonesian Agency for Meteorology, Climatology and Geophysics)[4]—including temperature, humidity, rainfall, and solar radiation—were combined with three widely used and open-access drought indices: the Vegetation Health Index (VHI),[5] the Keetch–Byram Drought Index (KBDI),[6] and the Palmer Drought Severity Index (PDSI)[7] (Abatzoglou et al., 2018; Kogan, 2022; Takeuchi et al., 2015).

Correlation and multiple linear regression analyses for 2007–2022 were conducted because this represents the longest period for which all indices and corresponding ground station data were available. These analyses were used to identify an index suitable for capturing persistent drought conditions. Trend slope was analysis to identify villages experiencing intensifying drought, while low standard deviation values indicated stable, persistent signals rather than short-term anomalies (Esit and Yuce, 2023; Gebrechorkos et al., 2020; Gumbel, 1963). Then the KBDI grid data were overlaid on village boundaries before ranking the 470 villages across the watershed. Applying these criteria narrowed the list to 21 villages showing consistent drought signals.

From the 21 villages, Kaluppini and Ranga (see Fig. 1) were purposively selected as theoretically representative cases that combine verified drought exposure with steep terrain, overlapping forestry and agricultural governance and active NGO-led adaptation initiatives. These reflect the institutional complexity and environmental stress, making them suitable sites on upland watershed for examining how adaptation support interacts with complex governance system to shape land use decisions.

2.2. Data collection

We employed a mixed-methods approach combining qualitative, quantitative and spatial data. Primary data were collected through semi-structured interviews with 35 farmer households (R1–R35) in Kalupini and Ranga, which have 668 households (276 and 392, respectively) and 435 people registered as farmers (digitaldesa.id, 2025). Interviews were conducted with farmer households who had at least 15 years of residence to ensure farmers had experienced drought events and institutional changes, covering 129 plots—defined as individual land parcels managed by small farmers (see Fig. 1). In total, 37 farmers were interviewed, but two interviews were excluded from the analysis due to incomplete and inadequate information.

Interviews were organised with five keys thematic area including: 1) household and land characteristics; 2) drought experience and perceived environmental change; 3) land use trajectories and crop transition over time; 4) decision-making process; and 5) institutional influence, including access to information, assistance programmes, informal and formal rules shaping land use choice.

We applied purposive sampling, selecting participants most relevant to the research focus—based on land topography, crop, assistance and participation across programmes—and continued until theoretical saturation was reached, when multiple subsequent interviews yielded no new substantive insights into land use trajectories. Eight government officials were purposively selected to represent key decision levels and agriculture and forest programmes which affected land use decision—regency, provincial and national level—including the Village Head, the Agricultural Extension Coordinator, officials from the Ministry of Environment and Forestry, Provincial and Regency Agriculture Offices, and the Badan Perencanaan Pembangunan Daerah (BAPPEDA; Provincial Development Planning Agency). Two local NGOs involved in adaptation and social forestry initiatives were also interviewed.

Participatory GIS (PGIS) and focus group discussions (FGDs) were carried out using A3 maps and the Avenza mobile mapping tool, which allows offline navigation and recording of spatial data directly on digital maps to identify land locations and conditions, water sources and drought impact. The farmer dataset was georeferenced at the farmer's land to trace land use transitions. This transition from initial and current crop data was compared to identify dominant conversion pathways (e.g., paddy to maize, cocoa to maize, forest to maize). Then, it linked to farmer accounts of when and why decisions were made, allowing for an understanding of crop change to be mapped against major governance interventions and assistance programmes. Secondary data complemented this analysis and included policy documents and programmes from national, provincial and regency agriculture and forestry agencies.

[4] *BMKG. Accessed at* https://dataonline.bmkg.go.id/

[5] *VHI, NOAA. Accessed at* https://www.star.nesdis.noaa.gov/smcd/emb/vci/VH/vh_ftp.php

[6] KBDI, *Accessed at* https://developers.google.com/earth-engine/datasets/catalog/UTOKYO_WTLAB_KBDI_v1.

[7] *PDSI, Accessed at* https://developers.google.com/earth-engine/datasets/catalog/IDAHO_EPSCOR_TERRACLIMATE

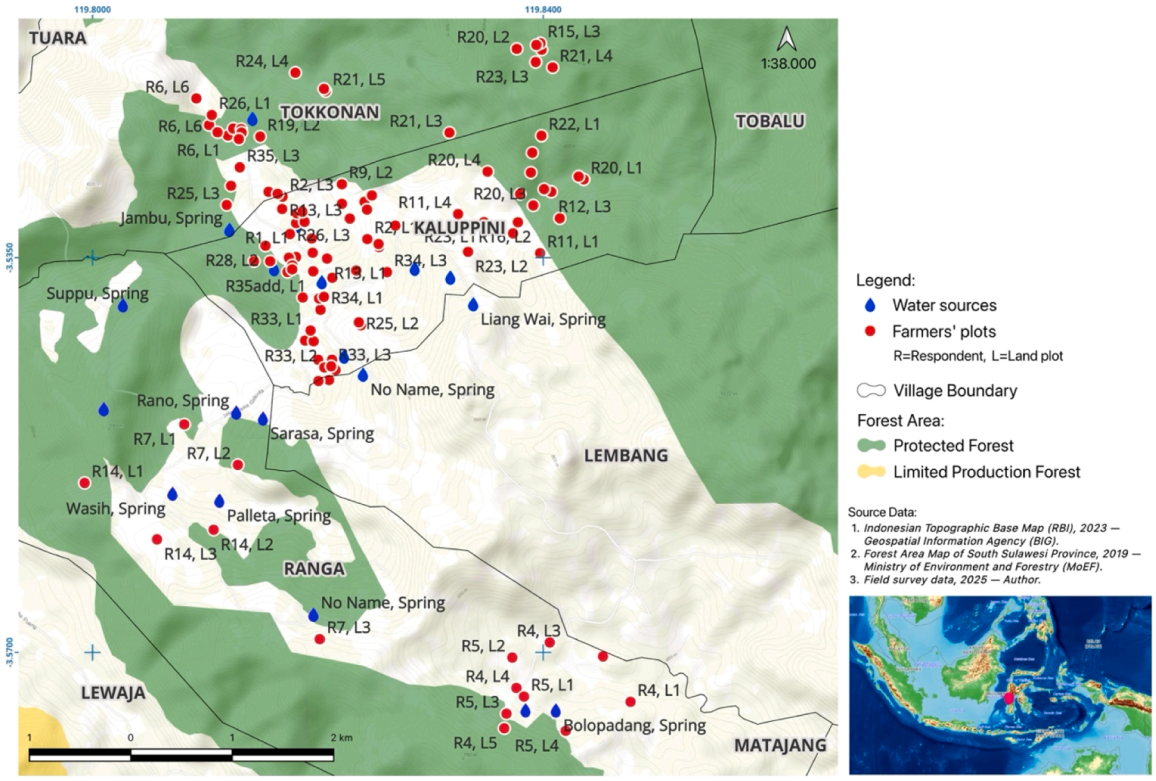

Fig. 1. Kalupini and Ranga villages with farmers' plots.

2.3. Data analysis and validation

We analysed the data by combining qualitative interpretation, spatial and institutional analysis. Interview transcripts were coded using NVivo 15 (Mortelmans, 2019; Wong, 2008), with initial coding being broad and inductive to capture recurring themes including farmer experiences and strategies, governance practices and any programme interventions. As the research developed, we gradually refined these themes and interpreted them through IAD framework. This links the emerging codes to Ostrom's rule types (including boundary, position, choice, payoff, scope, aggregation and information rules) and traces how rules-in-use shaped land use choices and changed through different institutional settings. Each rule pattern was synthesised across households and governance levels to identify broader institutional dynamics.

We cross-checked the spatial data collected through participatory GIS (Dunn, 2007; Carver, 2003) with farmer interviews to determine where land use changes had occurred. This allowed us to locate areas of paddy and cocoa abandonment, maize expansion and agroforestry, then to connect these transitions with institutional processes. To strengthen reliability, we also triangulated the evidence across different sources—farmers, government officers, NGOs and policy documents.

3. Results

3.1. Characteristics of the sample and land use pattern

Of the 35 farmers interviewed, 28 were men and 7 were women. Ages ranged from 33 to 71 years, with a mean age of 53 years. Most participants were between 50 and 69 years old, with a dominance of older labour in upland farming. Farmers' households reported between one and nine dependents, with a mean of five dependents per household. Most respondents had primary education (43%), followed by high school education (37%). All farmers were members of agricultural groups and two of them also participated in community forestry (HKm) groups.

These farmer interviews covered 129 land plots with a total area of 74 ha. When earlier land use was traced, only 125 plots were identified as some plots had been split or divided among relatives and new land had been opened. Currently, most farmers' households cultivate maize, and a small number retain small areas of paddy along riverbanks where water access remains dependable. Farmers (R2, R4, R8, R10, R25, R28, R33) described problems with irrigation and drought periods since 2000, for example R8 mentioned "*the paddy land dries quickly after rain*", made paddy terraces harder to maintain. Cocoa production also reduced as trees aged and pests became more common. Over time, plots that once supported paddy, cocoa or mixed agroforestry were shifted to crops that did not depend on water supply. This supports the village selection based on meteorological drought indicators as farmers and local authorities pointed to clear signs of severe drought, including maize terraces and dried land and rivers.

Fig. 2 summarises these land use changes, where the Sankey diagram does not include years because each plot has its own cultivation history; instead, it compares the initial land use when the plot was first managed with its current condition. Although the timing of transitions varies, the overall pattern shows that maize has become the dominant outcome across a wide range of former uses. Among the 129 plots, thirty distinct transitions were recorded, with the most significant being the shift from paddy to feed maize, which accounted for 32.5% of plots. Other transitions into maize were also from forest margins (18.7%), cocoa (15.4%) and grasslands (11.4%), reflecting a broad restructuring of land use in the upland watershed.

The timing of maize adoption is illustrated in Fig. 3, which shows the number of farmers planting maize for the first time. The fluctuations broadly follow national policy cycles, particularly during the 2014–2024 Jokowi administration, when UPSUS programme (Special effort for paddy, maize, soya beans), recurring seed assistance and Village Fund infrastructure investments expanded rapidly. Early adopters appeared before 2010 (e.g., R3, R11, R30), relying on

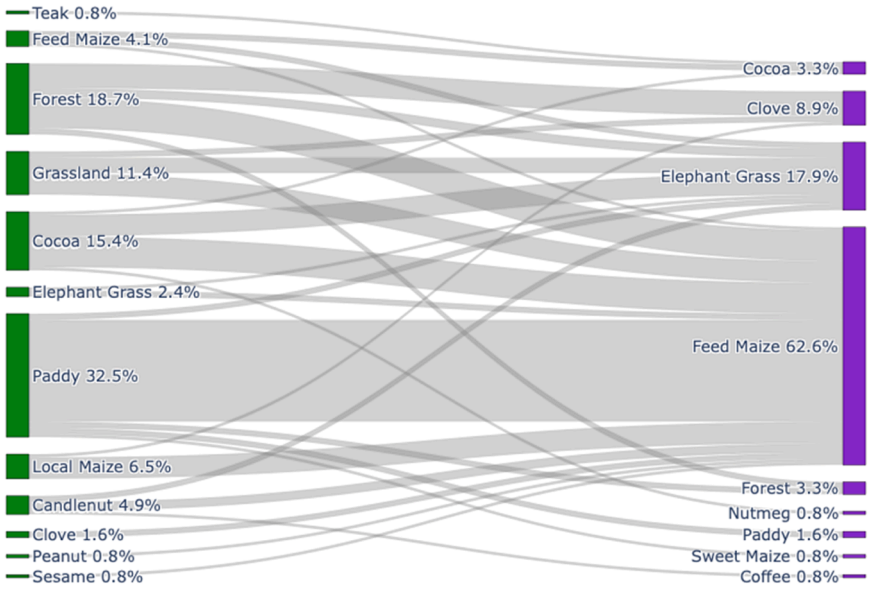

Fig. 2. Land use transitions: Initial (green) to Current (violet), *(Source: Author's fieldwork data, 2025)*.

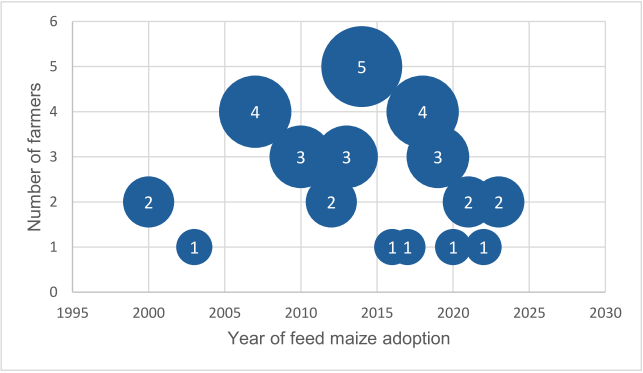

Fig. 3. Number of farmers cultivating feed maize for the first time, by year, *(Source: Author's fieldwork data, 2025)*.

purchasing a small number of seeds, but widespread adoption took place once maize seed assistance became routine, with upland road access improved. This pattern has been evident since 2020, when maize adoption became closely linked to a repeated cycle of maize assistance programmes. Many farming households have cultivated maize despite early hesitation, mainly because free inputs arrived each season and maize could be sold more easily.

These patterns suggest that the shift towards maize in Kaluppini and Ranga reflects more than farmer preference alone. Fig. 2 shows how land use changed across individual plots over time, while Fig. 3 illustrates when farmers first adopted feed maize and how these changes align with major programme cycles, particularly in the period after 2015. Although these shifts may appear to be spontaneous responses to drought, pests and ageing crops, their timing points to a more structured process, which coincides with the Jokowi administration. For this reason, it is important to examine how practical rules and programme arrangements shaped these decisions, which the following analysis addresses.

3.2. Institutional pathways of rule erosion

Evidence from Kaluppini and Ranga shows that rule erosion emerged gradually from the interaction of agricultural assistance, community forestry (HKm) group and Village Fund policy incentives under drought conditions. These programmes did not eliminate rules, but changed how boundary, scope and payoff rules operated in practice. Across successive program cycles, these shifts narrowed the practical set of land use and support options available to households, reducing their ability to respond flexibly under drought conditions.

Boundary rules began to collapse most visibly in maize assistance, which drove substantial land use change towards monoculture maize. Agriculture assistance, especially for seed and fertiliser, is officially channelled through Calon Petani Calon Penggarap Lahan (CPCL; Prospective Farmers and Prospective Landowners) lists, which were formally intended to identify eligible farmers and land. In Kaluppini and Ranga, all individual farmers were registered in farmer groups and all received seeds—mainly sourced from the national food security programme. Since provincial and regency level programmes did not target maize for these villages, they allocated a negligible budget for maize, regardless of whether they intended to cultivate it. Families with multiple group memberships received allocations more than once per season, making maize seed effectively a free input throughout the year. This assistance also reached non-farmers—including Enrekang city residents, civil servants and local traders—who were repeatedly identified across interviews as recipients of maize seed, like R4 mentioned that "even people in the city who are not farmers can also receive maize seed assistance".

Farmers who initially had no intention of planting maize simply passed the seeds on to neighbours and relatives, or sold them at a low price. However, because they continued receiving seeds year after year—from channels including Village Fund s, provincial, regency, local NGOs—they gradually began planting maize themselves and eventually expanded maize cultivation. This process shows how repeated assistance cycles progressively weakened targeting boundaries. Boundary rules were further weakened after COVID−19, as 20% of Village Fund s were redirected to food security programmes, which translated into maize distribution. This made maize seed available to every household and created an additional open-access channel that extended assistance regardless of local socio-ecological preferences.

In contrast, boundary rules for perennial crops and agroforestry remained narrow. Perennial programmes from the Ministry of Agriculture and the Provincial government distributed small numbers of seedlings, required farmer registration and plot identification and did not repeatedly supply the same farmer groups. HKm group participation was tied to formal permits; named members were authorised to plant within the licensed forest permit area. Non-members were excluded from forestry or agroforestry seedlings. This produced a clear asymmetry in

boundary rules, where maize assistance became almost non-excludable and the perennial and forestry support remained tightly filtered.

Scope rules, which determine where activities may legitimately take place, have also loosened. Before maize assistance expanded, farmers used the landscape in line with slope and moisture conditions, with rainfed paddy planted in valley bottoms and terraced areas, perennials on workable slopes and steeper land near the forest left less intensively cultivated. As maize programmes scaled up in parallel with drought conditions, seed distribution no longer distinguished between these areas. Maize has now been planted continuously on paddy terrace (see Fig. 4), including land that had previously been lightly used or left uncultivated, which was pointed out during interviews (see Fig. 5).

Village Fund road projects expanded access to upland areas, making it easier to transport bulky maize harvests from steeper plots—unlike paddy, cocoa or peanuts, which are produced in smaller volumes and are far less demanding to transport. In contrast, scope rules for HKm remained fixed, with planting restricted to designated compartments with specified mixtures of timber and non-timber species and planting outside permit boundaries explicitly prohibited. As a result, scope rules for maize became widely permissive and forestry remained tightly defined, enabling maize to extend into locations where other land uses remained constrained.

Payoff rules also shifted in ways that further locked farmers into short-cycle maize. Maize assistance offered an immediate economic return because it eliminated almost all upfront production costs, where seeds were free, no verification or survival obligations applied, and farmers could expect income within the same season. This low-risk, rapid-return structure was reinforced by the presence of collectors and maize taxis, which guaranteed a predictable market and quick cash flow even from steep or marginal plots. However, these short-term payoffs masked significant hidden costs. Farmers repeatedly described not only declining soil fertility but also increasing soil erosion, noting that the topsoil was easily washed away by rain. They also highlighted growing dependence on chemical fertilisers and yield reductions on fragile upland soils—costs that no institution assumed responsibility for addressing.

In contrast, perennial and HKm programmes involved delayed and often uncertain returns. Farmers had to prepare proposals to receive a limited number of seedlings and meet survival targets. Farmers were also required to follow planting arrangements that increased coordination costs without offering short-term returns. These uneven payoff structures meant that maize became the main income option that worked across different land types during drought periods, despite its long-term environmental and livelihood risks. As a result, payoff rules no longer guided crop choices by ecological suitability or long-term value but instead favoured short-term gains, reinforcing the boundary and scope rules already in place.

Under this configuration of rules, when boundary rules around maize assistance collapsed toward open access, scope rules for maize became loose while those for forestry remained strict and payoff rules increasingly favoured short-cycle maize over longer-term land uses. Since higher-level maize programs had low administrative costs, they limited farmer options from the top down, effectively making maize the default strategy for households. As this cultivation grew, it spread to steep slopes in forest margins and HKm areas, locking in these land use patterns.

Fig. 4. Maize cultivated on former paddy terraces. *(Source: Author's fieldwork data, 2025)*.

Fig. 5. Maize expansion into areas previously left uncultivated. *(Source: Author's fieldwork data, 2025)*.

3.3. Eroded rules restructured farmer decision-making and land use

The rule configurations described above were reflected in the land use trajectories observed across the 129 plots in Kaluppini and Ranga. Environmental stressors, including drought, water shortages and pests, placed stress on existing farming systems, but these pressures alone do not explain the observed transitions. Rather, it was the combination of weakened rules governing maize assistance and restrictive rules for perennials and HKm that shaped how farmers adjusted their land use choices in practice. Three dominant trajectories emerge from the empirical material.

The first is the shift from paddy to maize in valley bottoms and terraces. Farmers reported that irrigation channels now dry more frequently and more quickly after rainfall, making paddy increasingly unreliable. Some of these plots could have been converted to other crops, but access to perennial seedlings was limited and often occurred once (e.g., cocoa, coffee, nutmegs). In contrast, maize seed arrived repeatedly through different assistance channels—agricultural programmes based on CPCL lists and Village Fund allocations based on households—and was not tied to specific land plots. When paddy failed or became too risky, households introduced maize on these fields, initially as a response to dry years. As maize assistance continued across successive seasons and no comparable support existed for alternative crops, maize gradually became the dominant use of former paddy terraces.

The second trajectory is the replacement of ageing cocoa and mixed perennial systems with maize. In the upper Saddang, cocoa decline has long been linked to ageing trees and pests, yet rehabilitation programmes provided small quantities of seedlings, targeted limited groups and cannot be received more than once, leaving many farmers without continued programme support. At the same time, most households received maize multiple times over the years, regardless of plot verification, eligibility or intended planting.

These channels made maize appear administratively low cost and highly flexible, with no sanctions, no monitoring requirements and no rules governing planting arrangements. However, this apparent flexibility masked significant hidden costs. By removing boundary, scope and payoff constraints from maize while maintaining stricter rules for perennials, the system narrowed the set of viable adaptation options and reduced local flexibility. When rehabilitation support for cocoa and mixed perennial systems failed to arrive in practice, farmers cultivated maize in declining plots and repeated assistance cycles gradually locked households into a path-dependent shift towards maize. Even though farmers also recognised the longer-term risks, institutional arrangements make it difficult to re-establish other options.

The third trajectory is the expansion of maize onto upper slopes and forest margins. Since 2015, Village Fund road projects have improved access to upland areas that were previously difficult to reach with harvested crops. Because maize seed distribution did not distinguish between slope classes or proximity to forest boundaries and because seasonal programmes reached almost all households, maize began to be planted in newly accessible locations, including on steep plots that had been lightly used or left uncultivated before. This shift was reinforced by the commodity's bulk characteristics, which require maize to be transported in large volumes by truck, unlike cocoa, peanuts or paddy, which are lighter, often stored locally and do not depend on immediate road access.

New roads made maize farming in upland areas easier and cheaper, allowing farmers to plant in places that were previously difficult to reach. HKm members were still required to follow strict agroforestry rules within their permit areas and limited support, while non-forestry groups could not access forestry seedlings or agroforestry support. Upper slopes and forest land outside HKm areas were increasingly used for maize, reflecting the interaction between loosened maize scope rules and fixed forestry rules.

Across these trajectories, the pattern reflects a structural response to institutional arrangements. Gradual weakening maize seed assistance lost its boundaries, spreading to anyone, any slope and it became accessible everywhere, including on land that had previously been uncultivated or abandoned. Agriculture officers from multiple levels reported no formal restrictions on maize on steep slopes and attributed land conversion to farmers decisions.

On the other hand, perennial and forestry offered limited options by narrow and demanding rules that restricted participation and imposed higher burdens on farmers. Under the drought conditions and declining yields, rules weakened unevenly, leaving farmers with a pathway that remained consistently low administrative costs without restrictions. Rule erosion influences land use choices and operates to push farmers towards short-cycle maize. This narrows available options and creates the conditions for what we term assistance-led maladaptation, rather than expanding flexibility to adapt.

3.4. Assistance-led maladaptation as the outcome of rule erosion

The land use trajectories in Kaluppini and Ranga show that the erosion of boundary, scope and payoff rules—intensified by recurring drought pressures—has produced institutional arrangements with unintended outcomes. We refer to this as assistance-led maladaptation, which describes maladaptive land use outcomes caused by weakened institutional rules that allow agricultural assistance programmes to spread indiscriminately and override ecological and governance safeguards. As seed assistance becomes effectively open-access and spatial limits collapse, farmers are channelled into land uses that increase vulnerability—widespread maize monoculture on fragile uplands. This indicates that the shift is a structured institutional process rather than a failure of individual choice.

A pattern across farmers' narratives suggests that this institutional shift has produced visible environmental degradation, particularly in the form of soil depletion and accelerated erosion. For example, R8 mentioned "*during rainfall, soil is carried away*" and R35 demonstrating this by lifting soil by hand from elsewhere and pressing it onto steep slopes before planting maize and. As boundary and scope rules weakened, maize spread onto steep slopes and forest margins, where perennial cover had previously stabilised the landscape, making formerly productive plots thinner, more fragile and prone to runoff.

To maintain yields under these conditions, farmers reported a sharp increase in chemical fertiliser use—roughly half a sack per hectare for cocoa and five to eight sacks of maize per hectare—reflecting how soil degradation is closely associated with expanding monoculture. Farmers linked recent erosion and landslides in nearby areas to maize farming on steep slopes. They explained that planting maize in these locations makes the likelihood of similar events. These events were reported in places where weakened rules allowed cultivation to spread beyond ecological limits.

A second indication of assistance-led maladaptation is the progressive lock-in to maize monoculture, which reduced rather than expanded household adaptive flexibility. When farmers experience drought and declining cocoa yields, this can encourage diversification, but weakened maize rules and restrictive perennial and forestry programmes left farmers with few viable alternatives. Repeated seed assistance with minimal administrative burden made maize the safest choice for farmers. Even farmers who recognised declining yields and long-term risks described being unable to shift course because institutional structures—not agronomy—limited their flexibility. In comparison, perennial and HKm programmes involved more complex requirements and higher coordination costs. As soils changed and rehabilitation support failed to reach farmers, returning to perennial or agroforestry systems became increasingly difficult. This process gradually locked households into maize-based pathways and strengthened path dependency.

The last indication of assistance-led maladaptation is the way these institutional constraints become misinterpreted as farmer-driven expansion. Local authorities sometimes attribute erosion, forest-edge cultivation or slope conversion to farmers choices, whereas our empirical material shows that these outcomes reflect institutional asymmetries arising from the gradual weakening of rules. These arrangements created hidden costs—soil degradation, landslide exposure and increasing fertiliser dependence—that were borne by farmers but not recognised in programme design. The situation appears as farmer-driven degradation, masking how rule erosion driven by overlapping assistance channels and weak cross-sector governance shifted responsibility downward. This shift towards maize can be understood as an outcome of broader institutional dynamics than individual farmer decision-making.

4. Discussion

4.1. Rule erosion as an institutional outcome

This study suggests that maize expansion shaping land use patterns in the upland Saddang watershed cannot be fully understood as an autonomous adaptation or as farmer error (Dobler-Morales et al., 2021; Müller et al., 2017; Ostrom, 2009). Although drought, water scarcity and declining cocoa production created strong pressures and motives, these conditions were channelled by repeated cycles of maize assistance that structured incentives in ways that progressively narrowed the range of viable responses available to households (Cash et al., 2006; Streeck and Thelen, 2005). As these rules weakened unevenly, maize became the most accessible and least constrained option, while perennials and agroforestry became increasingly difficult to sustain, making maize cultivation into steep upper slopes and ridge areas where it cannot be read simply as an adaptive choice in response to stress (Ostrom, 2005; Quinn et al., 2007).

This pattern is consistent with arguments in institutional economics. North (1991), (1995) showed that rules requiring verification and monitoring tend to remain limited in reach, whereas low-cost rules diffuse rapidly, so the direction of institutional change depends on relative transaction costs. Asymmetric costs then generate increasing returns, lowering the marginal cost of the cheaper option each cycle while raising the cost of switching away (Pierson, 2004). The resulting trajectory is gradual change through policy drift—formal rules persist while hollowing out in practice—and policy layering, where new programme cycles reshape existing rules without explicit repeal (Mahoney et al., 2010; Streeck and Thelen, 2005). The upper Saddang case specifies this view at the community scale, where maize assistance spread under low administrative costs and perennial or HKm rules remained tightly filtered, producing the uneven weakening of boundary, scope and payoff rules that narrowed farmers' options—what we conceptualise

as rule erosion.

A key implication is that institutional looseness does not automatically expand adaptive space. Rules-in-use are often expected to increase flexibility when relaxed (Ebbesson, 2010; Ostrom, 2005; Quinn et al., 2007), but in the upper Saddang case relaxation was applied unevenly and the result was a narrower rather than wider set of practical options (Adhikari et al., 2004; Ching and Mukherjee, 2015; Cortner et al., 2024). Rule erosion should therefore not be conflated with adaptive flexibility.

This finding also extends research on maladaptation studies, which has shown how climate interventions can narrow options and shift vulnerability in unexpected ways (Biella et al., 2024; Burrows et al., 2025; Müller et al., 2017; Zango-Palau et al., 2024). The upper Saddang case adds a temporal dimension to that literature: maladaptive outcomes can emerge gradually through institutional weakening rather than through policy failure or mis-implementation, marginalising land use options that might otherwise have supported longer-term resilience.

These dynamics produce what we term assistance-led maladaptation, in which farmers shift towards consistently supported land uses even when those choices generate longer-term vulnerabilities, including soil degradation, increased dependence on external inputs and heightened exposure on steep terrain (Burrows et al., 2025; Dobler-Morales et al., 2021; Sirimorok et al., 2023)

4.2. Land use policy implications

The patterns observed in upland Saddang resonate with broader findings on land use change in topographically sensitive contexts. Yu et al. (2025) argue that reconciling food security with land use sustainability requires explicit zoning against forest conversion, while Kukulska-Kozieł et al., (2026) show that highland regions without land-market safeguards are particularly vulnerable to upland conversion. Our case demonstrates how national programmes such as UPSUS PAJALE operate as a de facto open-access regime on steep and forest margin. Beneficiary-based eligibility (CPCL) is therefore insufficient where rule erosion is operating, suggesting that the zoning and land market safeguards proposed in this literature need to be paired with mechanisms that limit the cumulative loosening of scope rules across repeated programme cycles.

A study in drought areas of western Ethiopia demonstrates that bundled rather than single practices climate-smart agriculture substantially improves household food security outcomes (Mwalupaso et al., 2025); research on large-scale agricultural investments in central Ethiopia critiques one-shot transfers for failing to embed farmers in durable support (Kebede et al., 2023); and a systematic review of the agricultural land use change literature places cross-sectoral coordination at the core of sustainable land management (Akmal and Mohammadi, 2025). Our findings align with these accounts but specify the mechanism, where repeated low-cost maize distribution sat alongside procedurally heavy perennial and HKm pathways, producing an asymmetric weakening of payoff rules that drove lock-in.

A defining feature of the Saddang case is its multi-level governance, a recurrent concern in polycentric governance scholarship is cross-sector fragmentation (Nagendra and Ostrom, 2012; Oberlack et al., 2018; Ostrom, 2010). Cross-sectoral coordination is widely identified as a missing element in land use governance and participatory mechanisms differentiate outcomes across highland regions (Akmal and Mohammadi, 2025; Kukulska-Kozieł et al., 2026). In Saddang, agricultural assistance overrode multi-level and cross-sector governance, channelling decisions into a single pathway. Reopening alternatives require provincial, regency and village-level programmes that offer viable options suited to local landscape conditions.

4.3. Limitations

This study has several limitations. The analysis draws on qualitative evidence from two upland villages and 35 farming households, providing depth of insight but limiting the extent to which the findings can be generalised across the wider watershed, despite village selection following a systematic rationale from an initial pool of 470 villages. The findings, reflect institutional dynamics specific to South Sulawesi's upland maize assistance context, which future comparative research could extend to other institutional settings.

Second, because farmers struggled to recall seasonal production costs and prices, this analysis deliberately avoided detailed economic-return analysis of payoff rules. Our argument about payoff rules, therefore, rests on the structural features of programmes rather than on quantified returns, leaving the relative weight of institutional versus market factors underspecified. Future research could focus on longitudinal cost and prices to explore market dynamics and how they interact with institutional erosion.

Third, this paper focuses on boundary, scope and payoff rules and does not examine all seven IAD rules at once, which would risk shallow analysis of each. Although the imperial material suggests that information, aggregation, choice and position rules may also have weakened over time, these dimensions are left for future research.

5. Conclusion

This study shows how both effects of climatic stress and policy-driven assistance have jointly shaped adaptation in the upper Saddang watershed. Repeated cycles of agricultural assistance turned maize seed distribution into open-access, leading farmer households to adopt short-cycle maize cultivation that has increasingly expanded onto steep slopes and forest margins, producing assistance-led maladaptation rather than autonomous adaptation.

The novelty of this research lies in introducing rule erosion to the IAD framework as a distinct institutional mechanism. Unlike institutional analyses that treat rule change as adaptive flexibility or macro-level drift and maladaptation studies that explain harmful outcomes through policy failure or mis-implementation, this paper shows how the gradual weakening of boundary, scope and payoff rules in practice narrows options by producing asymmetries that make certain choices appear low-cost and flexible. It extends the concept of erosion—previously developed in constitutional and international-norms scholarship—to community-level resource governance, reframing what often appears as spontaneous farmer adaptation as a structured institutional outcome.

These findings point to practical policy implications across administrative levels, where multi-level governance has collapsed into asymmetry instead of buffering each sector's failures. A graduated approach is needed: at the national level, location- and slope-based filters embedded within CPCL and seed allocation to safeguard upland watersheds and forest margins; at the provincial and regency levels, balance across programmes through simplified registration, repeat eligibility and multi-year assistance so that perennial and agroforestry options are not procedurally disadvantaged; and at the village level, viable alternatives matched to local landscape and socio-ecological condition.

Rule erosion opens new directions for institutional research and maladaptation studies. Future work could test the mechanism in other regions, crops and programme types; integrate longitudinal economic data with institutional analysis; or trace the full IAD rule to assess how information, aggregation, choice and position rules interact with the three rule types examined here.

CRediT authorship contribution statement

Jon C. Lovett: Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Naufal Naufal:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Steve Carver:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Victoria Houlden:** Writing – review & editing,

Writing – original draft, Supervision, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

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