MYANMAR

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The Continuous Rise - During Economic Growth, the COVID-19 Pandemic, and Conflict - in the Adoption of Labor-Saving Agricultural Technologies in Myanmar

Evidence and Implications

USAID FROM THE AMERICAN PEOPLE

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ABSTRACT

After decades of isolationism and economic stagnation, Myanmar opened its economy in the beginning of the 2010s, leading to rapid economic growth (Myanmar's Gross Domestic Product (GDP) was almost 50 percent larger in 2020 than in 2011). But the COVID-19 health crisis that started in 2020 and a military coup in the beginning of 2021 – and the subsequent increase in conflicts, forced displacements, and migration – dramatically reversed that outlook, with Myanmar's GDP in 2022 estimated to be 13 percent smaller than three years earlier. The agricultural sector also changed accordingly during this period.

Based on large-scale farm surveys we find that:

1. Over the last decade there has been an increasing scarcity of agricultural laborers in rural Myanmar. While two-thirds of the farmers in the survey reported that they had a lot of choice in agricultural laborers in 2013 (ten years before the survey), this share had declined to 48 percent in 2019, and declined by another large 22 percentage points over the crisis years to 27 percent in 2022.
2. Agricultural input supply systems continued functioning surprisingly well during the crisis years and there were no major complaints about the availability of agricultural inputs, indicating the resilience of the private sector's distribution systems.
3. This reduced availability of agricultural labor, as well as the availability of alternative agricultural technologies, is reflected in farmers' technology choices. The adoption of labor-saving agricultural technologies – measured by the use of mechanization, herbicides, and direct seeding of rice – increased rapidly over the economic reform period. Adoption rates further increased, despite the massive economic downturn and upheaval, during the crisis years.
4. Over the span of only 10 years, the share of rice farmers that used tractors for plowing increased by 43 percentage points, combine-harvesters by 41 points, herbicides by 39 points, and direct seeding (or broadcasting) of rice - instead of transplanting - by 20 points. Over the crisis years (between 2019 and 2022), these shares increased by 3 to 6 percentage points.
5. Farmers in the most insecure areas, smallholders, or more remote farmers adopted relatively fewer labor-saving agricultural technologies, suggesting lower agricultural labor productivity increases for them, with important implications for their welfare.
6. The adoption of yield-increasing technologies (chemical fertilizer and improved seeds) increased during the economic reform period but decreased during the crisis years. As labor-saving technologies are found to be mostly associated with lower yields (the switch from direct seeding to transplanting is associated with an average yield decrease of 15 percent) this suggests these changes in technology adoption contributed to lower agricultural production during the crisis years.
7. The results overall indicate the importance of agricultural labor markets as a driver of change for agriculture in these fragile settings.

The findings from this research have a number of important implications:

1. The results illustrate the important role that the private sector can play in ensuring resilience of the agricultural sector in conflict-affected areas, where public sector agricultural service delivery is typically reduced.

2. Economic liberalization measures can rapidly lead to better agricultural outcomes - as measured by labor productivity improvements and the uptake of yield improving technologies - while insecurity and bad governance lead to worse performance of the agricultural sector.

3. Given rural labor scarcity, there is a rapidly increasing demand for mechanization. However, the import of new machinery and spare parts is reduced given stringent import regulations as well as the uncertain business environment. It seems therefore that additional training would be useful for the repair of old machinery as well as in the proper management of machinery. Moreover, while it is typically assumed that increasing mechanization leads to improved land productivity, this is not the case in Myanmar, indicating possible improvements in this area, e.g. through the adoption of improved rice harvesters.

4. The use of herbicides is on the rise. The agro-chemical sector in Myanmar is characterized by weak regulatory and enforcement mechanisms, possibly leading to public health and environmental problems that should best be better understood.

5. The increasing adoption of direct seeding of rice is leading to significantly lower yields compared to transplanting. While there might be benefits from the increasing adoption of direct seeding – notably higher labor use efficiency and lower methane emission due to higher water use efficiency – the adoption of improved direct seeding practices, such as integrated crop management techniques and improved weed management, might possibly help to reduce this yield gap.

“The Burmese civil war is the longest-running armed conflict in the world… In a way Burma is a place where the second World War never really stopped”

Myint-U (2007)

1. INTRODUCTION

Agri-food systems have changed rapidly in low- and mid-income countries over the last decades, driven by population growth, urbanization, policy reform, and improved road and communication infrastructure, among others (Barrett et al. 2022, Reardon and Minten 2020, Otsuka et al. 2023). The farm sector in these countries is reforming accordingly. An increasing spread of the use of improved and yield-increasing technologies is often seen, but not uniformly so (Sheahan and Barrett 2017; Bachewe et al. 2018). The adoption of labor-saving agricultural technologies is on the rise as well (Gallardo and Sauer 2018). While these changes have been well studied, the agricultural sector in fragile environments has received less attention as representative data on agriculture are often lacking in these contexts. Because most of the global poor making a living from the agricultural sector does so in a fragile environment, understanding technology change in this setting is crucial (World Bank 2021).

We look at the case of Myanmar, a poster child of fragility.[1] Myanmar’s economic development was held back due to decades of ethnic conflict, military rule, centralized planning, and economic mismanagement (Brown, 2012). However, the country partly liberalized its economy in the beginning of the 2010s, leading to rapid economic growth, albeit starting from a low base. Among others, import restrictions were reduced, the banking sector reformed, limits on internal and external migration were relaxed, and the economy opened to international mobile phone service providers. Major investments in road and energy infrastructure were made as well. The GDP of the country, in US dollars, increased by almost 50 percent over the period 2011 to 2020.[2] However, persistent conflicts continued between the central government and different ethnic armed organizations.[3]

The onset of the COVID-19 pandemic and a military coup in the beginning of 2021 halted economic growth, and between 2020 and 2023 the welfare improvements that had been achieved through prior economic growth reversed. The World Bank (2023) estimated that in 2022 Myanmar’s economy was around 13 percent smaller than three years earlier and 30 percent smaller than it would have been in a scenario with no pandemic and military takeover. The military coup led, among others, to a disruption in the delivery of private and public services as a large number of employees left the junta controlled public sector, severe liquidity shortages led to a crisis in the banking sector, restrictions in the use of internet and phone services limited information exchange, and severe mobility constraints hampered transport and trade.[4] Furthermore, there was a notable escalation in conflicts, paralleled by a surge in the population of Internally Displaced People (IDPs) within the nation. By mid-2023, the count had surged to 1.6 million individuals, a stark increase since the onset of 2021, primarily attributable to the pervasive conflicts (OCHA 2023). Food insecurity also increased, with 1 out 4 people estimated to be moderately or severely food insecure at the end of 2022 (OCHA 2023).

[1] Fragility is defined by the OECD as a combination of exposure to risk and insufficient coping capacities of the state, system and/or communities to manage, absorb or mitigate those risks. It is measured across economic, environmental, political, security, societal, and human dimensions by 8-12 indicators per dimension. Sixty countries were identified to be fragile in 2022, accounting for a quarter of the world’s population and three-quarters of people living in extreme poverty worldwide (OECD, 2022). Myanmar is one of these 60.

[2] In nominal terms, based on data from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=MM

[3] Moreover, at the end of 2016, Myanmar witnessed the Rohingya genocide and an accompanying humanitarian crisis, with Bangladesh hosting almost one million Rohingya refugees since (Myint-U 2019).

[4] The local currency (the MMK) depreciated, contributing to high price inflation in 2022, with the cost of a basic food basket 50 percent higher at the end of the year compared to the beginning (MAPSA 2023a) and fuel prices triple the level in the middle of 2023 compared to the beginning of 2021 (World Bank 2023).

No updated and representative data have been available on the agricultural sector in the country during this volatile decade.[5] The agricultural sector is crucial though for Myanmar's economy and people's livelihoods: 70 percent of the population and 87 percent of the country's poor live in rural areas where agricultural livelihoods are predominant (CSO, UNDP, and WB 2020). Agriculture and its associated agro-industries are a key sector of the rural and national economy, employing half of the total labor force and contributing one-third of the national GDP–about 23 percent directly in farm incomes and another 11 percent in agro-processing, distribution, trade, agricultural export businesses, and food retailing (Diao et al. 2023).

Based on unique large-scale farm surveys, we find that the farming environment has been substantially affected by the consequences of the military coup. Perceived insecurity by crop farmers has been high and almost a quarter of the farmers reported that they could not move around without serious concern for security in the beginning of 2023. A substantial share of communities also reported not cultivating land because of insecurity and some of them had fields burnt and harvests destroyed. Moreover, some farmers needed to dispose of farm assets, especially given a dramatic drop in the provision of formal and informal safety nets (Boughton et al. 2023). On the other hand, agricultural input supply systems continued functioning surprisingly well and there were no major complaints on the availability of these inputs, indicating the resilience of the private sector's distribution systems in these fragile environments.

There were also significant changes in agricultural labor markets over the last decade. Over the economic reform period, the manufacturing and service sector grew rapidly, and significant growth was seen in formal labor markets, and in welfare (CSO, UNDP, and WB 2020). Agricultural wages also increased substantially, and agricultural labor markets tightened due to urban growth and rural emigration (Filipski et al. 2020). During the crisis years, however, labor markets have been significantly disturbed. Most importantly, after the military coup, a large share of the population moved, domestically and internationally. MAPSA (2023b) estimates that in the first half of 2022, a high 6.5 percent of Myanmar's population migrated, mostly due to economic upheaval and lack of employment opportunities, but also because of conflicts. This migration contributed to large labor shortages in rural Myanmar, and therefore to the way agriculture is done.

We focus our study on three agricultural technologies with strong links to agricultural labor to understand to what extent they have been affected by these large changes over the last decade.[6] First, mechanization is increasingly adopted in low- and middle-income countries driven by the availability of cheaper machines, electricity, and fuel, but also by the offered labor savings, reduced drudgery, and convenience (Diao et al. 2020; Belton et al. 2021). Second, herbicides replace manual weeding, and they are now widely adopted in African and Asian agriculture because of international patent expiration, the availability of cheap generic products, complementarity to changing agricultural management techniques (such as direct rice seeding), and the increased labor costs in a number of

[5] While evaluations of changes in the agricultural sector have been done through localized surveys in the middle of the economic reform period (Belton et al. 2019, 2021), data have been lacking on changes in the agricultural sector at a nationally representative scale at the end of the reform period and since the crisis years started.

[6] Our analysis contributes to our knowledge in several ways. First, we analyze agricultural technology adoption data in fragile settings. Most international studies on agriculture and fragility have focused on agricultural price changes in such environments (e.g. Bellemare, 2015; Dube and Vargas, 2013) – partly as such data are relatively easy to collect – but studies on agricultural productivity and on the adoption of agricultural technologies are rare. Exceptions are Arias et al. (2019), who find conflict being associated with more subsistence production, and Adelaja and George (2019), who find important adjustments in labor markets due to conflict. However, none studied changes in agricultural technologies used. Second, we focus on several labor-savings technologies, an understudied topic as the international literature has mainly focused on yield-increasing technologies in low- and middle-income countries (e.g. Evenson and Gollin 2003). Some authors have recently looked at the adoption of mechanization (Diao et al. 2020) and herbicide use (Naylor 1994; Haggblade et al. 2017) in low- and middle-income countries while others looked at gender impacts (Vemireddy and Choudhary 2021), but knowledge is still limited. There is also limited research looking at large-scale changes in labor-intensive seeding practices (Naylor 1996). While some authors have looked at the impacts of seeding practices on labor-productivity explaining the low adoption of seemingly promising new yield-increasing technologies (e.g. Vandercasteelen et al. 2018; Moser and Barrett 2006), areas sampled were however small. Finally, we contrast adoption of labor-savings with yield-increasing technologies, and high economic growth periods with economic contraction, and assess heterogenous adoption patterns for vulnerable and poor farmers, i.e. conflict-affected, smallholders, and remote farmers.

these countries (Haggblade et al. 2017; Naylor 1994). Finally, agricultural management techniques can also change because of changes in labor markets. A chief example is the transplanting of rice, which has been the most common method of crop establishment throughout Asia, ensuring higher yields through uniform plant stands and better weed control. However, manual transplanting is tedious, requiring up to 30 person-days per hectare.[7] It has therefore been increasingly replaced by the labor-saving direct seeding method (Naylor 1996; Malabayabas et al. 2012).

We find remarkable rapid uptake of these three labor-saving agricultural technologies over the economic reform period and even in the face of major governance and insecurity issues in the country, surprisingly also during the crisis years. Over the span of only 10 years, the share of rice farmers that used tractors for plowing increased by 43 percentage points, combine-harvesters by 41 percentage points, herbicides by 39 points, and direct seeding (or broadcasting) of rice - instead of transplanting - by 20 points. Over the crisis years, these shares increased by only 3 to 6 percentage points. The observed pattern contrasts with the adoption of yield-increasing technologies, such as improved seeds and chemical fertilizer, which saw an increase during the economic reform period but a decrease in crisis years. We also find strong heterogeneous effects in the adoption of these labor-saving technologies. The most conflict-affected areas show significantly lower rates in adoption of modern labor-saving technologies, seemingly partly because of lower labor scarcity issues in these areas but also because of more severe income declines (MAPSA 2023c). Smallholders and more remote farmers – measured in travel times from major cities as well as from the center of townships ("the last mile") – also participated less. This finding suggests the lowest agricultural labor productivity increases for remote and conflict-affected smallholders, with important implications for their welfare.

The structure of the paper is as follows. In Section 2, we give background information on the case of Myanmar. Section 3 presents data and methodology. Descriptives on conflict and input markets are presented in Section 4. Section 5 then looks at different agricultural technologies and how adoption has changed over the last decade and over the crisis years specifically. We also look at determinants - focusing on the role of poorer and vulnerable farmers - of levels and changes in adoption of agricultural technologies and then triangulate our findings. We finish with conclusions and implications in Section 6.

2. BACKGROUND

After the second World War, political parties in Myanmar could not reach an agreement in adopting a federal constitution and armed resistance by ethnic minorities has therefore continued since. Moreover, the country has suffered from economic mismanagement. In the early independence years, all land was nationalized and throughout the military socialist era, from 1962 to 1988, government policy built a state-controlled system around this government land ownership. Compulsory cropping plans, production quotas and mandatory sales to government marketing agencies, often at below market prices, eroded farmer incentives and led to long-term stagnation of agricultural productivity and competitiveness. Following large-scale protests in 1988 and a change to a non-socialist military government, stringent control by the state was gradually loosened (Okamoto 2008).

In the beginning of the 2010s, an ambitious economic policy reform program was implemented, with the government partly liberalizing Myanmar's economy as seen in the relaxation of import restrictions, reform of the banking sector, reduced limits on internal and external migration, and improved acceptance of FDI, as seen in investments by international mobile phone service providers. The move away from the socialist legacy in the beginning of the 2010s also included new agricultural policies such as the relaxation of cropping controls, and a shift from the focus on production quantities

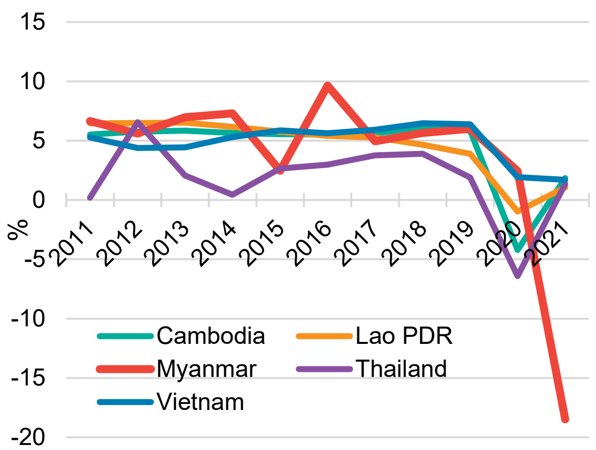
[7] See http://www.knowledgebank.irri.org/training/fact-sheets/crop-establishment/manual-transplanting

to the quality of people's life, as noted in the setting of poverty reduction targets (Okamoto 2020). This gradual liberalization of Myanmar's economy led to significant economic growth and poverty alleviation over the period 2010-2019 (CSO, UNDP, and WB 2020, Ferreira et al. 2021).

The economic transformation – and welfare improvement - was however interrupted in the beginning of the 2020s. The COVID-19 and political crises created unprecedented challenges to the functioning of Myanmar's economy. The COVID-19 crisis led to large income declines overall and to disruptions in Myanmar's agri-food system because of stringent long-lasting mobility restrictions (Boughton et al. 2021; Headey et al. 2020). However, the problems were mostly temporary, like experiences noted in other countries. Overall, GDP growth declined in 2020 but was still higher than what was noted in other South-East Asian countries (Figure 1).

The political crisis, after a military coup in the beginning of 2021 followed by a Civil Disobedience Movement (CDM), caused more severe economic problems, i.e. in the banking and finance sector, in international and local trade, and in the transport sector, among others. The junta increasingly enlarged their control of key sectors and economic actors and emphasized self-sufficiency. In the face of increasing sanctions by most Western countries and the blacklisting by the Financial Action Task Force (FATF) it promoted ties with Russia, China, and Thailand (UNDP 2023). Moreover, the currency of Myanmar, the kyat (MMK), rapidly depreciated. This led to a dramatic contraction of Myanmar's economy (Figure 1) as well as a worsening of households' welfare (Boughton et al. 2023). In 2022, the World Bank estimated that Myanmar's economy was approximately 13 percent smaller than it had been three years prior, and 30 percent below the projected size in a scenario devoid of the pandemic and military takeover (World Bank 2023).

Figure 1: Annual GDP per capita growth in a regional context

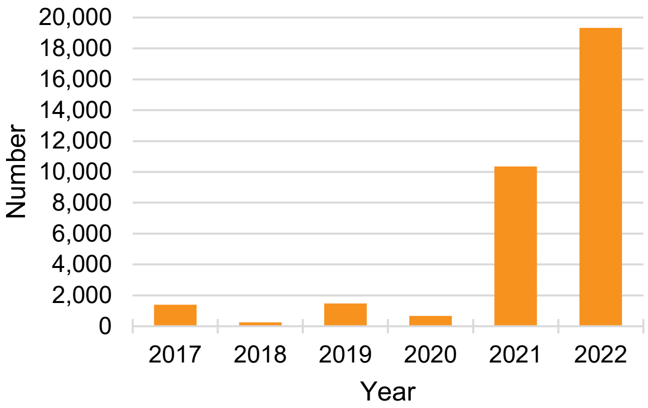


Source: World Bank (https://data.worldbank.org/)

Moreover, increased, and widespread conflicts in the country became a major hindrance for economic activities. Figure 2 gives an overview of the change in the number of fatalities due to violent events over the period 2017-2022. Compared to the period 2017-2020, we see a sharp increase in 2021 and a subsequent further doubling of these fatalities in 2022. On top of this, it was estimated that since the beginning of 2021 to the middle of 2023 60,000 civilian properties had been burnt or destroyed and that 1.6 million people were displaced due to clashes and insecurity (OCHA 2023).[8] This was in addition to the 300,000 IDPs displaced before the coup as well as the almost 1 million Rohingya refugees that fled to Bangladesh in 2016/2017 (OCHA 2023).

[8] ISP (2023) reports an even higher number. It estimates that 2.7 million people were displaced due to violent clashes in April 2023 compared to two years earlier.

Figure 2: Number of fatalities related to violent events in Myanmar, 2017 - 2022 (annual total)



Source: ACLED (2022).

3. DATA AND METHODOLOGY

3.1 Data and Descriptives

The Myanmar Agricultural Performance Survey (MAPS) was implemented by phone after the monsoon and after the dry season in 2022, as well as after the same seasons in 2023. Enumerators were trained in employing CATI (computer-assisted telephone interviewing) to collect representative data from crop farmers across all states and regions of Myanmar during these interviews. The farm households were selected based on their participation in previous rounds of the Myanmar Household Welfare Survey (MHWS) and their status as a farming household (MAPS 2022). MAPS attempted to reach all MHWS farming households from that survey.9

Table 1 presents descriptives of the farmers interviewed after monsoon – the most important agricultural season in Myanmar - in the beginning of 2023. This is the sample that we will rely on mostly for this analysis.10 There were 4,961 farmers interviewed during that survey. The average farm size of the interviewed households was 5.6 acres. As has been shown in other surveys, paddy is a very important crop for farmers in Myanmar. In the monsoon of 2023, 60 percent of the interviewed farmers reported growing paddy. This compares to much lower shares of pulses (11 percent) and maize (10 percent), other important crops in the country.

The main management decision maker on these farms was male in 56 percent of the cases and 47 years old on average. Three percent of the agricultural decision makers had no education at all while 86 percent indicated that they had completed standard levels from 1 to 10. Five percent reported that they had obtained a bachelor's degree. The number of household members working on the farm was on average 2.0. Like results from earlier surveys, there were relatively more adult men working on the farm (56 percent of all labor) than women (44 percent of all labor) (Lambrecht et al. 2021), while work by children (defined as less than 15 years old) was reported by respondents to be less important.

[9] To obtain a nationally representative sample for MHWS, a master database was constructed in which all phone numbers were stratified at the township level, so that the amount of phone numbers in each township was proportional to the population size of each township (from the 2014 Census) (MAPSA 2022a). Then households were selected randomly to be called in each township. Households were sampled at the township level to minimize oversampling of well-connected and/or wealthier townships. To ensure that women, famers, and less educated individuals were not under sampled, minimum targets by state were set for women (half of all respondents), rural location, farming livelihood, and education level. A weighing coefficient was further created to ensure representativeness.

[10] The herbicide adoption data are obtained from round 4, fielded in Q3 of 2023.

Table 1: Descriptives sample

	Unit	Mean	Median	Standard Deviation
Total number of farmers surveyed	Number	4,961		
Share of farmers cultivating rice	%	60		
Share of farmers cultivating pulses	%	11		
Share of farmers cultivating maize	%	10		
Average size farm	Acres	5.6	4.0	5.8
Background of main farm management decision maker of farm				
Age	Years	47.4	47.0	11.6
Gender	% male	56.6		
Highest level of education achieved				
None	%	2.9		
Standard 1-10	%	86.4		
Bachelor	%	3.1		
Other	%	7.6		
Household members working regularly on the farm				
Adult male	Number	1.1	1.0	0.7
Adult female	Number	0.9	1.0	0.8
Children	Number	0.0	0.0	0.1
Total workers	Number	2.0	2.0	1.1
Remoteness				
Travel time to city of at least 50,000	Hours	2.9	2.3	2.1
Travel time to center township	Hours	0.8	0.5	0.8

Source: Authors' calculations based on MAPS

For our analysis, we rely heavily on recall data. We focus on those elements that should be easy to remember as well as on periods that were milestones, i.e. the last year before the COVID-19 and coup crisis started, as well as the situation a decade ago, i.e. when the economy was starting to open. To reduce recall error, we also focused on major changes in production practices and kept recall questions of these changes to simple categorical variables. Nonetheless, we acknowledge that such recall questions are prone to measurement error (De Nicola and Giné 2012, de Weerdt et al. 2014) and they are therefore a caveat of the current study. To the extent possible, we complement recall data by these households with other sources of information. For the evaluation of international trade in machinery and pesticides, we rely on the United Nations' Comtrade data.[11]

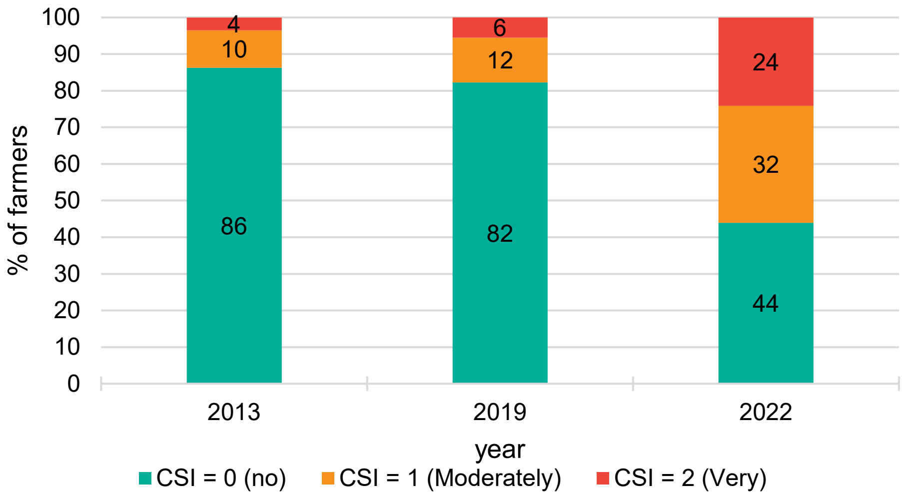
To assess spatial issues in our assessment, we rely on two remoteness measures. First, we estimate transport times in hours traveled from the center of the township to a major city of at least 50,000 people using transport infrastructure and landscape features (land use, rivers, lakes, and slope obtained from the Myanmar Information Management Unit). We assigned a travel speed to each of the road types (major, secondary, tertiary, tracks/other) in the geographic information system (GIS) data, ranging from 75 to 10 kilometers per hour and combined the GIS layers into a friction (or impedance) grid converted into one-kilometer grid cell raster layers. Slope is also considered to model uphill and downhill movement. We estimate travel times, on average, at 2.9 hours from the township that the farmer resides in (Table 1). Second, we asked farmers in the survey to estimate the time it takes to travel by commonly used transport means to the center of the township that they reside in. That travel time was on average 0.8 hours (Table 1). In further analysis, farmers are

[11] http://comtrade.un.org/

assigned to a remote and non-remote group, using the median of these estimated travel times as the cut-off.

We use publicly available datasets from the Armed Conflict Location & Event Data (ACLED) program for measurements of incidences of violence and conflict at localized levels (Raleigh et al., 2010). ACLED collects data on types of violence and fatalities associated with political violence and protests across the globe, sourced from official publications, media reports, civil society (e.g. NGOs, humanitarian agencies, etc.), local staff, or other sources. Dates and locations of these events are registered as well in ACLED's database. ACLED (2023) used these data to create a Conflict Severity Index (CSI), which classifies the severity of the conflict in countries in four categories: limited, moderate, high, and extreme. Following Steinhuebel and Minten (2023), we implement the same methodology at the level of townships in Myanmar. To assure enough observations in each severity category, we reduced the four categories to two, with the first category reflecting limited and moderate severity and the second category high and extreme severity. Figure 3 shows the distribution of households for these three categories over the three years studied. It illustrates the clear worsening of conflicts over time. While 86 percent of the farmers was living in a township without noticeable conflicts in 2013, this share was only 44 percent in 2022. In 2022, 24 and 32 percent of crop farmers in our sample were residing in very insecure (category 2) and moderately insecure (category 1) townships, as defined by this index.

Figure 3: Share of farmers by Conflict Severity Index category and year



Source: Authors' calculations based on MAPS

3.2 Methods and Hypotheses

We estimate the following model:

$$A_{hrt} = \alpha_h + \sum_{t=1}^{n} \beta_t \, Y_t \; + \gamma \, CSI_{rt} + \sum_{t=1}^{n} \delta_t [\, Y_t * R_h] + \; \varepsilon_{hrt}$$

The dependent variable A_{hrt} measures the adoption of an agricultural technology by household *h* at time *t* in area *r.* The CSI_{rt} variable measures the severity of the conflict in area *r* at time *t*. R_h is a vector measuring remoteness of the farmer and the size of the farm. α_h reflects household fixed effects, Y_t are yearly dummies, and ε_{hrt} is an error term measuring unobserved factors. We have observations over several years for the same households and we therefore rely on household fixed effect models, which allow us to control for those household characteristics that do not change over time. β_t measures to what extent adoption practices change over time for the base group of households (i.e., not remote and large farmers), γ_t measures the impact of conflict severity, and δ_t measures the gap in adoption between smallholders and households with larger land holdings and more remote and less remote households with the base group households. As our dependent variables are 0/1 dummies, we rely on the estimation of Linear Probability Models.

We expect changes in the use of labor-savings and capital-intensive goods because of changes in relative prices over the economic reform and crisis periods. During the economic reform period, wages increased (because of easier migration locally and internationally) (Filipski et al. 2020) and capital costs decreased (because of a reduction in licensing requirements). This is expected to lead to factor substitution along a production isoquant, i.e. higher use of capital-intensive and labor-saving practices and we therefore hypothesize β_1 to be positive. Because of the fragility of the economy during the crisis period, a range of effects could transpire. First, labor costs might increase in line with capital costs, leading to contraction of the agricultural sector and a shift to a lower isoquant. Second, agricultural labor could become relatively cheaper because of the collapse of the off-farm economy (e.g. Adelaja and George 2019), and less employment opportunities, leading to less intensive use of labor-saving practices. Third, agricultural labor could become relatively more expensive because of demand for male fighters and the migration out of insecure economies (MAPSA 2023b). Fourth, agricultural labor could also become relatively cheaper, because conflict cuts off migration networks for economic migrants. We will empirically estimate – through the coefficient β_2 – the effects that dominate in the case of Myanmar.

To assess differential changes for poorer and vulnerable farmers, we further interact time trends with conflict severity, farm size, as well as remoteness of the farm. Conflict severity is expected to lead to less adoption of modern imported labor-saving technologies given the difficulty to make these technologies available and because of bigger negative economic impacts and therefore more severe income declines of farmers in conflict affected areas (MAPSA 2023c). As small farmers are typically less labor constrained than bigger farms, we expect that they will participate less in the adoption of labor-saving technologies, leading to gaps in the adoption between small and big farms (e.g. Forsyth and Springate-Baginski 2022). Remoteness of households has been shown to be an important determinant of lower adoption rates of improved agricultural technologies in other studies (Vandercasteelen et al. 2018; Damania et al. 2017; Steinhuebel and Minten 2023) and we therefore also expect that remote households will have lower adoption rates in this case. We therefore hypothesize δ_t to be negative for these poorer and vulnerable farmers.

4. CONFLICT AND AGRICULTURAL INPUTS

4.1 Conflict and Insecurity

Farmers were asked in each MAPS about their perceptions on insecurity in the area that they were residing in. At the national level, we see a high level, and a substantial worsening over time, in perceived insecurity. While 82 percent of the farmers indicated that they were living in a 'secure' or 'very secure' situation in the beginning of 2022, that share declined to 72 percent of the farmers a year later (Table 2). The share of farmers indicating that they were living in a 'very insecure' area increased, at the national level, from 4 to 9 percent. Moreover, almost a quarter of the farmers indicated that they could not move around without serious concerns for security at the time of the survey in 2023, almost a 3-percentage point increase compared to a year earlier (Table 2). Farmers were also asked if fields were not cultivated or if fields were burnt or destroyed or not harvested because of conflict in their area. At the national level, 4 and 9 percent, respectively, of the farmers indicated that this was the case in their area.

Table 2: Perceptions on insecurity

		2022	2023
Perceptions of insecurity by farmers			
Very insecure	%	3.7	9.1
Somewhat insecure	%	14.2	18.0
Secure	%	43.0	36.2
Very secure	%	38.5	36.1
Prefer not to answer	%	0.6	0.7
Total	%	100.0	100.0
Cannot move around without serious concern for security	%	20.3	22.8
Crops or field were burnt or destroyed or not harvested because of conflict in the farmers' area	%	-	4.2
Fields were not cultivated in my area because of conflict	%	-	8.6

Source: Authors' calculations based on MAPS

We assess the correlation of the Conflict Severity Index (CSI) measure with these reported levels of insecurity and the perceived impacts of conflict in the famer's community (Table 3). To do so, we use a simple logit model and therefore redefine the perceived insecurity response to a 0/1 dummy, by putting the "very" and "somewhat" insecure answers in one "insecure" category. The results show that residing in conflict-affected areas, as measured by the CSI, significantly increases the probability of reporting worse perceptions of insecurity. Moreover, the more severe the conflict, the bigger the marginal impact, indicating higher levels of perceived insecurity. Residing in a very insecure area - as measured by the CSI - increases the likelihood of reporting feeling insecure by 32 percent. We further look at the associations with restrictions in mobility, destruction of fields and crops, and leaving land uncultivated due to conflict. We also find in these cases significant positive relationships, with higher measures of conflict severity being linked to a higher probability of impacts of conflicts on farming. These results overall suggest that the CSI measure at the township level is a good measure of the conflict experience and the insecurity felt by farmers – possibly impacting their behavior – and we therefore use this measure for the conflict severity measurement and its impact on agricultural technology adoption going forward. This is especially useful given the consistent availability of CSI data for the past decade.

Table 3: Link of reported insecurity and impacts of conflict by farmers with the Conflict Severity Index (CSI) – logistic model – marginal effects

	Unit	Perceptions on insecurity		Dangerous to move around		Destroyed crops or fields due to conflict		Fields not cultivated due to conflict	
		Coeff.	t-value	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
CSI group 1 (Moderate insecure)	yes=1	0.059	3.63	0.036	2.47	0.023	3.70	0.053	5.84
CSI group 2 (Very insecure)	yes=1	0.317	16.94	0.287	15.74	0.099	10.08	0.205	15.01
Number of observations		4,929		4,950		4,956		4,955	
F(2,n)		146.74		138.41		56.43		113.41	
Prob > F		0.00		0.00		0.00		0.00	

Source: Authors' calculations based on MAPS

4.2 Agricultural Input Markets

Farmers were asked to indicate the problems they had faced in acquiring different agricultural inputs – in particular agricultural labor, pesticides/herbicides, and mechanization - during the monsoon season of 2023. More than half of the farmers indicated that they had not faced any difficulties (Table

4). Only a relatively small percentage of farmers indicated that they were unable to find enough inputs or that inputs were not available at all (2 and 3 percent respectively for pesticides/herbicides and mechanization respectively), indicating the resilience of the input supply systems - almost exclusively run by the private sector - during these crisis years. The biggest problems were reported in agricultural labor markets where 14 percent of the farmers reported they could not find enough laborers or that laborers were not available at all.

Table 4: Reported problems in input markets (monsoon of 2023), share of crop farmers

	Unit	Agricultural labor	Pesticides/ herbicides	Mechanization
Financial difficulties to purchase inputs	%	3.9	4.7	6.5
Inputs have become more expensive	%	4.9	5.4	5.9
Cannot find enough of the inputs - inputs not available	%	14.2	1.8	3.2
Required to pay in cash, instead of on credit	%	0.6	0.2	0.4
Difficulty to travel to purchase inputs/high transportation costs	%	10.0	1.7	10.3
No difficulties	%	58.2	52.9	52.4

Source: Authors' calculations based on MAPS

Labor markets are very important in Myanmar as the use of hired wage labor in agricultural activities is common. It is estimated that almost 16 percent of rural households considered agricultural wages their most important source of income at the end of 2022 (MAPSA 2022b). However, large changes happened in these agricultural labor markets over the last decade, with increasing labor scarcity seen in agriculture because of widespread emigration from rural areas due to increasing employment opportunities in cities and abroad (Filipski et al. 2020). This is seemingly confirmed by a simple qualitative question asked to farmers in the MAPS (Table 5). While two-thirds of the farmers indicated that they had a lot of choice in agricultural laborers a decade before the survey, this share had declined to 48 percent in 2019, and declined by another large 22 percentage points over the crisis years to 27 percent in 2022. These changes are all highly significant.

Table 5: Changes in agricultural labor markets, reported by crop farmers

		2013	2019	2022	Significance of change	
		(1)	(2)	(3)	2019 vs 2013	2022 vs 2019
Choice between agricultural laborers						
- A lot	%	66.0	48.2	26.9	***	***
- A little	%	24.9	40.6	56.9	***	***
- No choice	%	9.1	11.2	16.1	**	***

Asterisks show significant differences at p-values: * p < 0.10, ** p < 0.05, *** p < 0.01; n.s.: not significant

Source: Authors' calculations based on MAPS

We assess the role of residing in conflict-affected areas on changes in agricultural labor availability over time by estimating a model where we use as a dependent variable a dummy reflecting "a lot of choice" between agricultural laborers, as reported by the farmers (Table 6). On the one hand, the increasing migration out of insecure areas – and the demands for fighters - might have led to less labor being available to work in agriculture (MAPSA 2023b). On the other hand, the reduction of employment opportunities because of the conflict-related contraction of the economy and the more limited travel opportunities because of rampant insecurity might have made more people available to work on the farm. It seems that the latter explanation is more likely as shown in significantly higher labor choice probabilities for the insecure areas. Moderately insecure and very insecure areas are 3 and 7 percent more likely to report more choice. However, given that insecurity increased especially in 2022, even in insecure areas they have had a reduction in choice compared to 3 years earlier.

Table 6: Determinants of choice in agricultural laborers - household fixed effects Linear Probability Model

		Choice	
		Coeff.	t-value
Year 2019	yes=1	-0.195	-22.39
Year 2022	yes=1	-0.428	-34.71
CSI group 1 (Moderately insecure)	yes=1	0.032	1.99
CSI group 2 (Very insecure)	yes=1	0.070	3.70
Intercept		0.667	107.65
Household fixed effects		yes	
Number of observations		8,969	
R2		0.11	

Source: Authors' calculations based on MAPS

5. ADOPTION OF LABOR-SAVING AGRICULTURAL TECHNOLOGIES

5.1 Trends Over Time

We focus on the use of herbicides on the farm in general and on two labor-savings technologies (mechanization and direct seeding) used for production of paddy rice, the most important staple in Myanmar. We asked farmers questions on the adoption of major agricultural practices 10 years before the survey (2013), three years before the survey (2019) - and therefore before the COVID-19 and political crisis unfolded - and during the last monsoon before the survey (2022) and present statistics – and test for the significance of change - accordingly.

Transplanting (or row planting) of paddy plants is a labor-intensive activity, generally leading to higher yields compared to direct seeding (Xu et al. 2019). We see a significant decline in transplanting being practiced over the last decade (see maps in annex). While 63 percent of the farmers reported practicing transplanting a decade before the survey, that share was reduced to 46 percent in 2019, and to 40 percent in 2022 (Table 7). The adoption of row planting increased slightly over the decade, by 2 percentage points. On the other hand, the adoption of the labor-saving direct seeding technique increased by 20 percentage points over the last decade. Over the last three years, it increased by 5 percentage points. The changes in direct seeding and transplanting during the economic reform period and the crisis years are all highly significant.

Table 7: Changes in agricultural technology adoption, share of farmers

	Unit	2013 (1)	2019 (2)	2022 (3)	Significance of change 2019 vs 2013	2022 vs 2019
Seeding methods						
Transplanting	%	63.5	46.1	40.1	***	***
Broadcasting	%	23.3	38.3	43.4	***	***
Row planting	%	7.5	9.0	9.9	*	n.s.
Combination	%	5.8	6.6	6.6	n.s.	n.s.
Herbicide use						
Glyphosate	%	2.6	21.7	23.0	***	n.s.
Selective herbicides	%	6.5	41.0	45.3	***	***
Mechanization						
Tractor use on most rice plots						
- Hired	%	25.6	53.0	56.4	***	**
- Owned	%	12.5	21.7	23.1	***	n.s.
- Both	%	1.1	3.0	3.6	***	n.s.
- No		60.8	22.3	16.9	***	***
If tractor used, type used						
- 4-wheel	%	25.2	39.3	43.5	***	***
- 2- or 3-wheel	%	70.5	54.9	50.5	***	***
- Both	%	4.3	5.8	6.0	*	n.s.
Combine-harvester used on most rice plots	%	10.2	45.0	51.1	***	***

Asterisks show significant differences at p-values: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; n.s.: not significant

Source: Authors' calculations based on MAPS

Herbicides have also been increasingly adopted, as shown in Table 7. Twenty-three and 45 percent of the farmers reported that they used glyphosate[12] and selective herbicides respectively in the monsoon of 2022, an increase of 19 and 39 percent respectively over the last ten years. While changes were small in recent years, adoption rates of herbicides still increased (but not significantly for glyphosate), even with large international price increases (prices for glyphosate were two to three times higher – depending on the month - in 2021 than they were in 2020[13]). We asked farmers specifically in the case that they adopted herbicides when they started doing so. The result of that question is shown in Figure 4. It shows the recent uptake of herbicide with approximately 50 percent of the users only starting to apply glyphosate and selective herbicides since 2018/19.

The increasing adoption of herbicides might be partly linked to the increase in direct seeding of rice and the dis-adoption of transplanting. Transplanting of rice is an effective method of weed management because of the flooding of rice fields.[14] As direct-seeded rice germination requires non-flooded conditions, it also allows at the same time more weeds to germinate, making weed management a major bottleneck for the direct seeding technology (Nawaz et al. 2022; Naylor 1994). This complementarity of herbicide use with direct seeding shows up in our data. During the monsoon

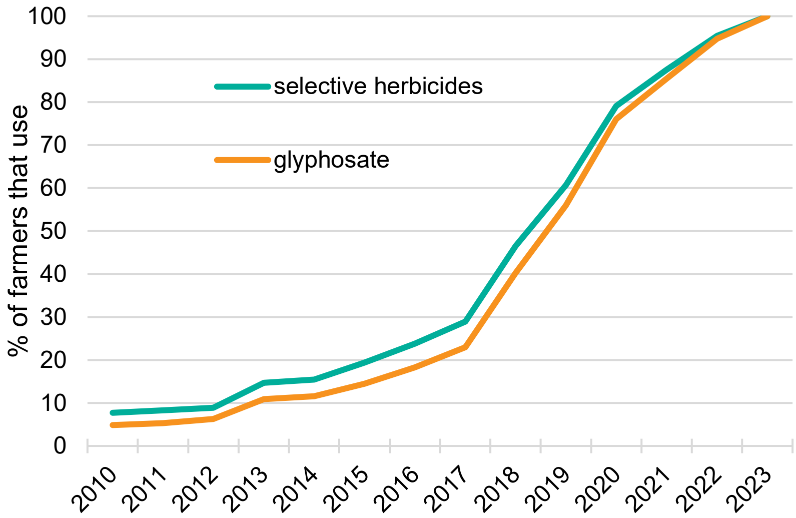
[12] Glyphosate is a non-selective herbicide that is typically applied before crop emergence to ensure minimal competition of weeds with crop growth.

[13] https://www.agribusinessglobal.com/agrochemicals/china-price-index-downward-price-trends-for-glyphosate-glufosinate-a-tipping-point-for-key-herbicides/

[14] While labor use is reduced at the early stage for direct seeding compared to transplanting, the more intensive weed management afterwards might require more labor for weeding or herbicide use during rice growth. Herbicide applications on rice fields are however less labor-intensive than transplanting, leading to overall labor reductions in the case of direct seeding. Typically, rice farmers in Myanmar would use selective herbicides twice a year – as stated by representatives of agricultural input companies.

of 2022, 75 percent of the direct seeding farmers used herbicides, while this was only 42 percent for the other rice farmers.

Figure 4: Year that farmers started using herbicides, for users

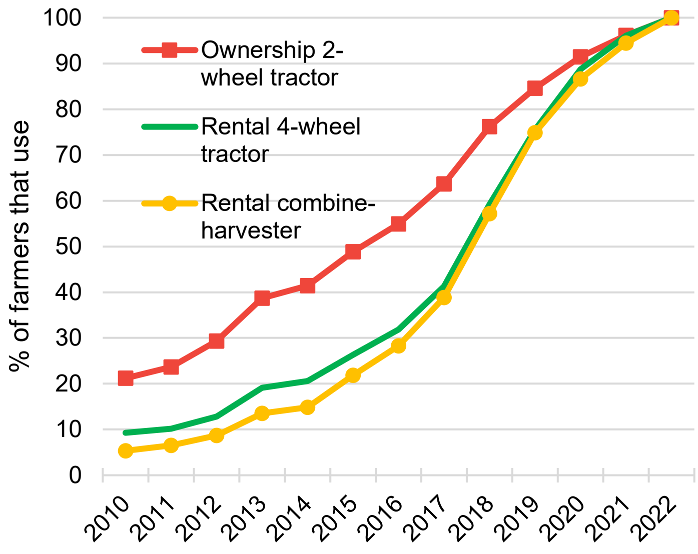


Source: Authors' calculations based on MAPS

In response to agricultural labor scarcity, and in the face of increased availability of machinery in the country, agricultural mechanization has rapidly taken off in Myanmar (Belton et al. 2021). Table 7 illustrates mechanization use by rice farmers over the last decade (for township level maps, see annex). Thirty-nine percent of the rice farmers reported relying on tractors for plowing in 2013. This increased to 78 percent in 2019 and further to 83 percent in 2022, all significant increases at the 1 percent level. Most of the use of mechanization was facilitated through mechanization service providers as seen in the high share of hired tractors for plowing, but we also see an important increase in ownership of tractors. Over time, we see an especially rapid increase in the use of the 4-wheel tractor for plowing (25 percent of all plowing by tractor in 2013 compared to 43 percent in 2022). Similar rapid changes in reliance on mechanization are seen in harvesting activities. While only 10 percent of rice farmers used combine-harvesters on most rice plots in 2013, this had increased to 45 percent in 2019, and increased further to 51 percent in 2022.

Farmers were also asked if they owned a 2-wheeled tractor and if so, since when did they acquire that tractor. In the case that they relied on rental services, they were asked since when they had been using these rental services for 4-wheel tractors and combine-harvesters. Ownership and use of mechanization rental services was still low in 2010, as less than 20 and 10 percent of the current users relied on these services at that point (Figure 5). Ownership of 2-wheel tractors has changed more gradually over time than the use of these mechanized rental services. About half of the owners of two-wheel tractors reported that they acquired their tractor before 2015. On the other hand, the use of rental services for 4-wheel tractors and combine-harvesters is a more recent phenomenon. Forty-three percent of the farmers only started renting machines since 2018. Thirteen percent of the users in 2022 only started using these mechanization services since the crisis period started in 2020, again illustrating the continuous increase since the crisis started.

Figure 5: First year owned/started with machinery by farmers, for users



Source: Authors' calculations based on MAPS

5.2 Heterogenous Effects

In this section, we look at the heterogeneous effect of conflict severity, remoteness, and the size of the farm in the adoption of labor-saving technologies. We find a significant association with conflict in the case of rice seeding methods (Table 8). The most conflict affected areas are more likely to adopt yield-increasing, but labor-intensive, seeding methods than more secure areas, partly because of relatively more labor being available in these areas, as found in Section 4. The effects are quite substantial as the probability of doing direct seeding in 2022 in the most conflicted areas was 6 and 7 percent lower in moderately insecure and very insecure areas compared to secure ones. On the flip side, significantly higher adoption rates of transplanting and row planting are noted in conflict-affected areas. The most insecure households were 8 percent more likely to practice it. We also see important effects of the size of the farm and of remoteness on these rice seeding practices. During the last monsoon, small farms were 7 percent more likely to practice transplanting or row planting compared to bigger farms. We also see during the last monsoon that more remote farmers within the township relied less on direct seeding and more on transplanting and row planting than farmers closer to the center of a township.

Table 8: Determinants of the use of seeding methods - household fixed effects Linear Probability Model

	Unit	Broadcasting		Transplanting or row planting	
		Coeff.	z-value	Coeff.	z-value
Year 2019	yes=1	0.193	12.02	-0.205	-12.27
Year 2022	yes=1	0.268	14.04	-0.287	-14.68
CSI group 1 (Moderately insecure)	yes=1	-0.059	-4.50	0.067	4.95
CSI group 2 (Very insecure)	yes=1	-0.068	-4.74	0.069	4.78
Interactions size of farm					
Year 2019*small farm	yes=1	-0.052	-3.18	0.060	3.58
Year 2022*small farm	yes=1	-0.047	-2.57	0.069	3.67
Interactions remoteness township to city					
Year 2019*remoteness city	yes=1	0.013	0.81	-0.017	-1.01
Year 2022*remoteness city	yes=1	0.026	1.38	-0.034	-1.80
Interactions remoteness within township					
Year 2019*remoteness in township	yes=1	-0.029	-1.81	0.029	1.77
Year 2022*remoteness in township	yes=1	-0.053	-2.91	0.051	2.75
Intercept		0.240	43.72	0.697	124.20
Household fixed effects		yes		yes	
Number of observations		8,935		8,935	
Number of groups		3,220		3,220	
F(10,n)		58.81		63.62	
Prob>F		0.00		0.00	
R2		0.04		0.05	

Source: Authors' calculations based on MAPS

We find a significant relationship between the uptake of glyphosate and insecurity (Table 9). The most conflict-affected areas had adoption rates that were 4 percent lower than in the most secure areas. While there are negative effects of insecurity on the adoption of selective herbicides, they are not significant at conventional statistical levels, suggesting that selective herbicides were taken up at similar levels in secure and insecure areas. Smaller farmers are much less likely to use glyphosate or selective herbicides compared to big farms, i.e. in the most recent monsoon, 9 and 11 percent less likely respectively. Remoteness overall has little effect on herbicide use as the coefficients are not significant.

Table 9: Determinants of the use of herbicides – household fixed effects Linear Probability Model

		Glyphosate		Selective herbicides	
	Unit	Coeff.	z-value	Coeff.	z-value
Year 2019	yes=1	0.258	17.40	0.432	25.17
Year 2022	yes=1	0.273	17.33	0.484	26.89
CSI group 1 (Moderately insecure)	yes=1	-0.007	-0.62	-0.006	-0.44
CSI group 2 (Very insecure)	yes=1	-0.041	-3.60	-0.017	-1.24
Interactions size of farm					
Year 2019*small farm	yes=1	-0.077	-5.18	-0.100	-5.81
Year 2022*small farm	yes=1	-0.090	-5.83	-0.112	-6.35
Interactions remoteness township to city					
Year 2019*remoteness city	yes=1	-0.009	-0.64	-0.004	-0.25
Year 2022*remoteness city	yes=1	0.003	0.20	0.012	0.68
Interactions remoteness within township					
Year 2019*remoteness in township	yes=1	0.013	0.89	-0.018	-1.02
Year 2022*remoteness in township	yes=1	0.028	1.82	-0.026	-1.47
Intercept		0.035	7.57	0.086	15.83
Household fixed effects		yes		yes	
Number of observations		9,887		9,913	
Number of groups		3,311		3,311	
F(10,n)		104.54		243.16	
Prob>F		0.00		0.00	
R2		0.09		0.17	

Source: Authors' calculations based on MAPS

We find significantly negative impacts of conflict on the adoption of mechanization, be it the use of any tractor for plowing, of a 4-wheel tractor for plowing, or of combine-harvesters (Table 10). The most severe conflict-affected areas especially show consistently significant negative effects on adoption. Except for the period 10 years ago - when adoption as well as insecurity levels were very low - we note a consistently lower uptake of mechanization in the most severe conflict-affected category compared to secure ones, between 3 and 4 percent lower. As overall trends in uptake were, however, very high (e.g. the difference in coefficients in regression of adoption of combine-harvesters in the years 2019 and 2022 is almost 10 percent), this implies that insecure areas also saw a positive increases in uptake over the crisis years.

While smallholders use any tractor for plowing as much as bigger farms (as shown by no significantly different coefficients in those interaction terms), they rely however less on combine-harvesters and 4-wheel tractors than bigger farms. More remote farmers are also significantly less likely to rely on bigger machinery. Farmers residing remotely from a city of at least 50,000 people have adoption rates of combine-harvesters that are 10 and 9 percent lower in 2019 and 2022 respectively than less remote ones. The coefficient has not changed over time though and the gap in adoption rate has therefore not widened over the crisis years. We also note that the "last mile" remoteness matters equally for the adoption of combine-harvesters but more so for the adoption tractors as seen by larger coefficients for remoteness within the township.[15]

[15] The importance of these last mile effects in agriculture has been shown in other studies as well (Minten et al. 2013).

Table 10: Determinants of the use of mechanization – household fixed effects Linear Probability Model

	Unit	Any tractor for plowing		4-wheel tractor for plowing		Combine-havester	
		Coeff.	z-value	Coeff.	z-value	Coeff.	z-value
Year 2019	yes=1	0.410	23.09	0.364	21.23	0.528	29.91
Year 2022	yes=1	0.467	24.56	0.439	23.09	0.623	33.20
CSI group 1 (Moderately insecure)	yes=1	-0.025	-1.85	-0.034	-2.66	-0.023	-1.74
CSI group 2 (Very insecure)	yes=1	-0.042	-2.77	-0.034	-2.31	-0.043	-2.84
Interactions size of farm							
Year 2019*small farm	yes=1	-0.022	-1.13	-0.068	-3.92	-0.101	-5.45
Year 2022*small farm	yes=1	-0.010	-0.50	-0.042	-2.21	-0.117	-5.96
Interactions remoteness township to city							
Year 2019*remoteness city	yes=1	0.003	0.16	-0.054	-3.12	-0.102	-5.53
Year 2022*remoteness city	yes=1	0.029	1.48	-0.050	-2.61	-0.094	-4.88
Interactions remoteness within township							
Year 2019*remoteness in township	yes=1	-0.025	-1.29	-0.099	-5.76	-0.094	-5.09
Year 2022*remoteness in township	yes=1	-0.029	-1.46	-0.108	-5.76	-0.110	-5.70
Intercept		0.405	64.11	0.119	20.30	0.105	16.96
Household fixed effects		yes		yes		yes	
Number of observations		8,931		8,931		8,939	
Number of groups		3,220		3,220		3,220	
F(10,n)		222.66		131.84		252.88	
Prob>F		0.00		0.00		0.00	
R2		0.19		0.12		0.20	

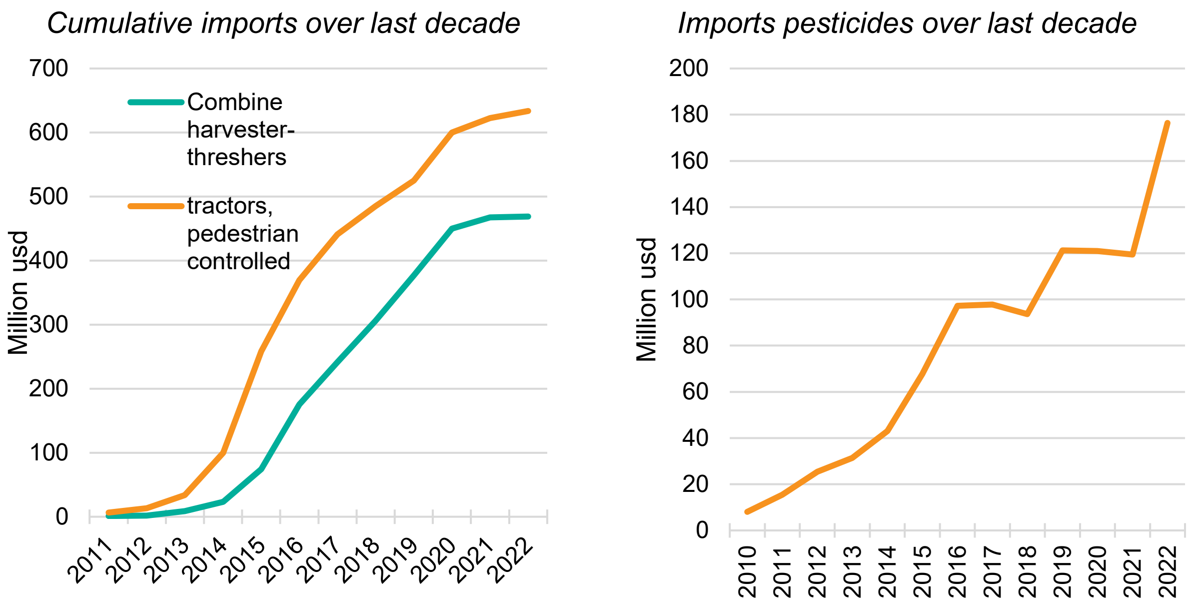
Source: Authors' calculations based on MAPS

5.3 Triangulation

We triangulate the results of our analysis in two ways. We compare the results with import data of modern inputs and we look at similar recall questions on yield-increasing agricultural technologies.

First, we assess to what extent use dynamics by farmers are confirmed with data on the import of some labor-saving technologies. Figure 6 shows the changes in the value of imports of combine-harvesters/threshers and pedestrian tractors over the last decade. While very few tractors or combine-harvesters/threshers were imported in 2010 to 2012, these imports have quickly taken off since, with peak imports seen in 2015 and 2016. It is noteworthy that imports dropped off significantly since the 2021 crisis years but were still happening, especially for tractors. Import statistics of pesticides and herbicides also show a similar picture over time. Myanmar imported 8 million USD of pesticides (including herbicides) in 2010, but that value went up to 120 million USD in 2021, 15 times as high (Figure 6). After stabilization in 2021, an increase of almost 50 percent in the value of imports was noted in 2022.

Figure 6: Import of machinery and pesticides in Myanmar



Source: Authors' calculations from Comtrade

Second, we compare the results of the labor-savings technologies with yield-increasing "green revolution" type technologies, i.e. seeds and chemical fertilizer.[16] Farmers were asked how they typically acquired rice seeds and if purchased, from whom. Between 2013 and 2019, we note an increase of farmers that purchased rice seeds (from 42 to 50 percent) (Table 11). Twenty-seven percent of rice farmers reported that they purchased the seeds from the formal market – the government or agri-input retailers or NGOs – in 2019. That share increased from 17 to 27 percent – a 57 percent increase – but declined again, and significantly, to 24 percent at the time of the survey, mostly because of less distribution by the government (possibly linked to the CDM movement). Distribution by the private sector has stayed at similar levels during the crisis years (a reduction by 1 percentage point) since a period of high growth between 2013 and 2019. In 2022, most of the farmers (58 percent) did not buy rice seeds, at almost similar levels as 10 years earlier. Purchasing branded seeds from formal sources is often seen as an indication of seed improvements (Bagamba et al. 2022). For those farmers that bought seeds, we asked if they bought them typically in branded bags. We see almost a doubling of the farmers that used branded seeds between 2012 and 2019 – from 11 to 21 percent. However, that share stabilized during the crisis years.

In the case of chemical fertilizer use, we see a significant increase in the share of farmers using urea between 2013 and 2019 (from 72 to 80 percent) and then a significant reduction between 2019 and 2022 (from 80 to 74 percent). Similar changes are seen in the case of compound fertilizer – an increase of 11 percentage points between 2013 and 2019 and then a decrease of 7 percentage points between 2019 and 2022. At the same time, use in 2022 was still higher than ten years earlier. Overall, we note a rise over the economic reform period and a fall during the crisis years in adoption rates of yield-increasing technologies, in contrast to the increase over time of labor-saving agricultural technologies.[17]

[16] While we have looked at labor-savings technology adoption, it is unclear what these changes mean for agricultural productivity in a country, an important consideration for policy makers concerned about food security in a country. While direct seeding leads to lower productivity, increased mechanization use might possibly lead to higher productivity.
[17] Comtrade data indicate that the imported quantities of chemical fertilizer in 2022 decreased substantially compared to 2019. While the value of imported chemical fertilizer increased from 413 million usd in 2019 to 586 million usd in 2022, the fertilizer prices increased significantly over that period. As Comtrade does not report quantities, we use the international urea price as an approximation to get at quantities. That approximation indicates a decline to half the level in 2022 compared to 2019.

Table 11: Changes in the use of seeds and fertilizers in rice production, share of rice farmers

	Unit	2012 (1)	2019 (2)	2022 (3)	Significance of change 2019 vs 2013	2022 vs 2019
Seeds						
Purchased from whom:						
- Other farmers	%	26.0	23.7	20.8	*	**
- Agri-input retailer/private sector	%	12.1	19.2	17.9	***	n.s.
- Government	%	4.7	7.3	5.6	***	***
- NGO	%	0.1	0.1	0.1	n.s.	n.s.
- Do not buy	%	57.1	49.6	55.6	***	***
Share of farmers using formal market	%	16.9	26.6	23.6	***	**
Share of branded in purchased seeds	%	26.2	41.2	46.4	***	**
Share of farmers using branded seeds	%	11.2	20.8	20.6	***	n.s.
Fertilizer						
Use urea on rice plots	%	70.3	79.4	73.1	***	***
Use compound fertilizer on rice plots	%	32.6	43.6	36.7	***	***

Asterisks show significant differences at p-values: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; n.s.: not significant

Source: Authors' calculations based on MAPS

5.4 Implications for Land Productivity

An important concern in fragile states is often the availability of food, as food production might be affected by changes in agricultural input use (Adelaja and George 2019). MAPSA (2023d) estimated that rice productivity declined by 2 percent and that increases in fatal violent events in Myanmar between 2020 and 2021 reduced Total Factor Productivity—a measure of the overall efficiency of all inputs used to produce rice—by about 4 percent on average in the short run. Between 2021 and 2022, rice productivity declined by more than 6 percent (MAPSA 2023e). While less intensive care and input use played a role in this reduction, droughts in important rice producing areas in the country mattered as well (MAPSA 2023e).[18]

To better understand the specific effects of the increasing uptake of labor-savings technologies on land productivity, we run a regression – relying on panel data from the largest rice plot for the monsoon of 2021 and 2022 of paddy farmers – to understand the relation of labor-saving technologies with rice yields. We present findings from pooled and fixed effect regression specifications in Table 12. The results show that the use of direct seeding has a significant yield-reducing effect compared to the use of transplanting or row planting in all specifications. The panel specification shows an average reduction of 15 percent, in line with yield-reductions seen in other countries (Xu et al. 2019). The use of herbicides is shown to lead to higher productivity – 4 percent – likely because of more effective and timely weed management. Given complementarity between herbicide use – to control for larger weed problems with direct seeding compared to transplanting – we also run a specification where direct seeding and herbicide use is interacted. The results show that farmers that practice direct seeding without herbicide use have rice yields that are 20 percent lower than transplanted rice while those that use herbicides on top of the direct seeding method

[18] This reduction in rice supplies, the international price increases in rice during that period, as well as the further depreciation of the local currency seemingly explain the high rice price increases seen in the country since.

reduce that difference to 10 percent. The use of mechanization is shown to increase yields in the pooled regression but not in the preferred panel data specification.[19]

Table 12: Determinants of rice productivity on largest rice plot

		Dep. variable = log(yield)					
	Unit	Pooled		Panel model 1		Panel model 2	
Independent variables		Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
Labor-savings technologies							
Broadcast	1=yes	-0.096	-6.34	-0.146	-4.19	-0.209	-4.52
Herbicides used	1=yes	0.040	2.79	0.040	1.95	0.000	0.00
Broadcast*herbicides used	1=yes					0.101	2.38
Tractor for plowing used	1=yes	0.080	3.81	0.083	1.36	0.083	1.37
Combine-harvester used	1=yes	0.172	11.25	0.029	0.79	0.027	0.75
Controls							
Fertilizer quantity	kg	0.003	8.29	0.005	6.86	0.005	6.71
Fertilizer quantity squared	kg	0.000	-2.12	0.000	-4.08	0.000	-3.91
Purchased seeds	1=yes	0.058	4.10	-0.012	-0.53	-0.011	-0.50
Upland field	1=yes	-0.313	-10.57	-0.297	-3.52	-0.294	-3.56
Organic fertilizer used	1=yes	0.049	3.90	0.017	0.68	0.018	0.73
Lime used	1=yes	0.072	3.86	0.020	0.69	0.024	0.81
Pesticides used	1=yes	0.014	1.04	-0.010	-0.43	-0.010	-0.44
Hired labor used	1=yes	0.095	4.41	0.090	1.91	0.086	1.83
Working household members	number	0.012	2.02	0.035	2.04	0.034	1.97
Drought	1=yes	-0.288	-9.15	-0.261	-8.29	-0.261	-8.28
Other shocks	1=yes	-0.173	-10.19	-0.174	-9.53	-0.173	-9.56
Year 2022	1=yes	-0.020	-1.63	-0.014	-1.88	-0.015	-2.01
Household dummies	1=yes	no		yes		yes	
Agro-ecological dummies	1=yes	yes		no		no	
Constant		6.630	180.98	6.706	69.75	6.732	69.89
Number of observations		6,101		6,101		6,101	
R2		0.23		0.19		0.19	

Source: Authors' calculations based on MAPS

6. CONCLUSIONS AND IMPLICATIONS

In secure non-fragile settings, labor market changes - and availability of labor-saving agricultural technologies - have been shown to be important drivers of agricultural transformation in low- and middle-income countries. Mechanization has been shown to rapidly take off in a number of these countries, driven by urbanization and improved off-farm rural employment opportunities (e.g. Diao et al. 2020; Otsuka et al. 1994; Belton et al. 2021). The adoption of herbicide use and the direct seeding of rice has also rapidly increased, because of similar driving forces (Malabayabas et al. 2012; Nawaz et al. 2022).

We study changes in the adoption of labor-saving agricultural technologies in Myanmar after economic reform (characterized by high economic growth) and after the COVID-19 health pandemic

[19] The insignificant effect of mechanization on rice yield is confirmed by a follow-up qualitative question asked to rice farmers regarding their perceptions on yield differences between harvesting rice manually and with combine-harvesters. 17 percent reported higher yields, 46 percent lower yields, while 35 percent evaluated them to be the same.

and a military coup (characterized by economic contraction). We find that there have been continuously higher uptakes of labor-saving agricultural practices during the economic reform as well as the crisis years. On the other hand, we see significant declines in the use of yield-increasing technologies such as improved seeds and fertilizer during the crisis years, after substantial increases during the economic reform period. We find that conflict is leading to a disruption of these labor markets – also documented by Adelaja and George (2019) in Nigeria – therefore leading to a similar drive for the further adoption of labor-saving technologies in fragile economies. However, there is strong heterogeneity, with farmers in most conflict-affected areas participating less, seemingly because less pronounced problems with labor availability, lack of sufficient income, or access to these technologies. We also find that the increasing adoption of labor-saving technologies leads to lower agricultural production in these settings, an important concern for food security.

The findings from our research have several implications:

1. As seen during the COVID19 pandemic, shocks to food systems often lead to rapid adoption of alternative technologies illustrating the surprising flexibility of these systems (Swinnen and McDermott 2022). We find such flexibility - as seen in the continued uptake of mechanization and herbicides and the dis-adoption of transplanting - even in these fragile environments. These changing patterns in adoption of agricultural technologies seemingly demonstrate the need for continued development assistance, on top of humanitarian assistance, to support these demanded changes, even in protracted crisis settings.
2. The results illustrate the important role that the private sector can play in ensuring resilience of the agricultural sector in conflict-affected areas, where public sector agricultural service delivery is typically reduced.
3. Economic liberalization measures can rapidly lead to better agricultural outcomes - as measured by labor productivity improvements and the uptake of yield improving technologies - while insecurity and bad governance lead to worse performance of the agricultural sector.
4. Given rural labor scarcity, there is a rapidly increasing demand for mechanization. However, the import of new machinery and spare parts is reduced given stringent import regulations as well as the uncertain business environment. It seems therefore that additional training would be useful for the repair of old machinery as well as in the proper management of machinery. Moreover, while it is typically assumed that increasing mechanization leads to improved land productivity, this is not the case in Myanmar, indicating possible improvements in this area, e.g. through the adoption of improved rice harvesters (Nawaz et al. 2022).
5. The use of herbicides is on the rise, characterized by weak regulatory and enforcement mechanisms, possibly leading to public health and environmental problems that should best be understood and addressed (Haggblade et al. 2023; Naylor 1994).
6. The increasing adoption of direct seeding of rice is leading to significantly lower yields than for transplanting. While there might be benefits from the increasing adoption of direct seeding – notably higher labor use efficiency and lower methane emission due to higher water use efficiency – adoption of more improved direct seeding practices, such as integrated crop management techniques and improved weed management, might possibly help to reduce this gap (Nawaz et al. 2022).
7. Most of the data collection efforts on agriculture in low- and middle-income countries have focused on yield-increasing inputs – such as improved seeds and fertilizer – but less detailed information is collected on labor-saving inputs that are important in some of these fragile contexts, and beyond. More efforts should therefore be put into collecting this relevant agricultural information in agricultural household surveys.

While the impact of economic reform, conflict, and conflict severity are obviously context specific, the study of the case of Myanmar provides insights on the transforming effects of economic reform as well as on the impacts that conflict and bad governance might impose on agricultural labor markets and consequent agricultural technology adoption. Our findings fit in with worldwide and historical trends of rapid transformation of agriculture when labor constraints are binding (Ruttan and Hayami 1984; Otsuka et al. 1994).[20] We find such rapid changes as well in fragile environments, but at less sophisticated levels than seen in more developed agricultural systems.

Our findings also suggest areas for future research. First, there is a need to collect data beyond green revolution technologies in low- and middle-income countries. Mechanization and herbicides are increasingly being used in low- and middle-income countries and agricultural household surveys typically collect few detailed data on these practices. Moreover, more information is required on agricultural management practices that might have important explanatory power for changes in labor as well as land productivity. Second, there is a need for similar assessments in other countries. It would be useful to understand to what extent such labor-saving agricultural technologies are spreading in other low-and mid-income countries, as well as in fragile economies. Third, our analysis relied heavily on recall data, and it would be important in future research to reduce the unknown recall errors with the use of panel surveys.

[20] While agricultural labor productivity is estimated to be lower than in other economic sectors - that is less the case when one considers skill differences and actual hours worked (Gollin et al. 2014) - this however is rapidly changing due to the spread of mechanization, automation, and A.I. (Christiaensen et al. 2020; Acemoglu and Restrepo 2019).

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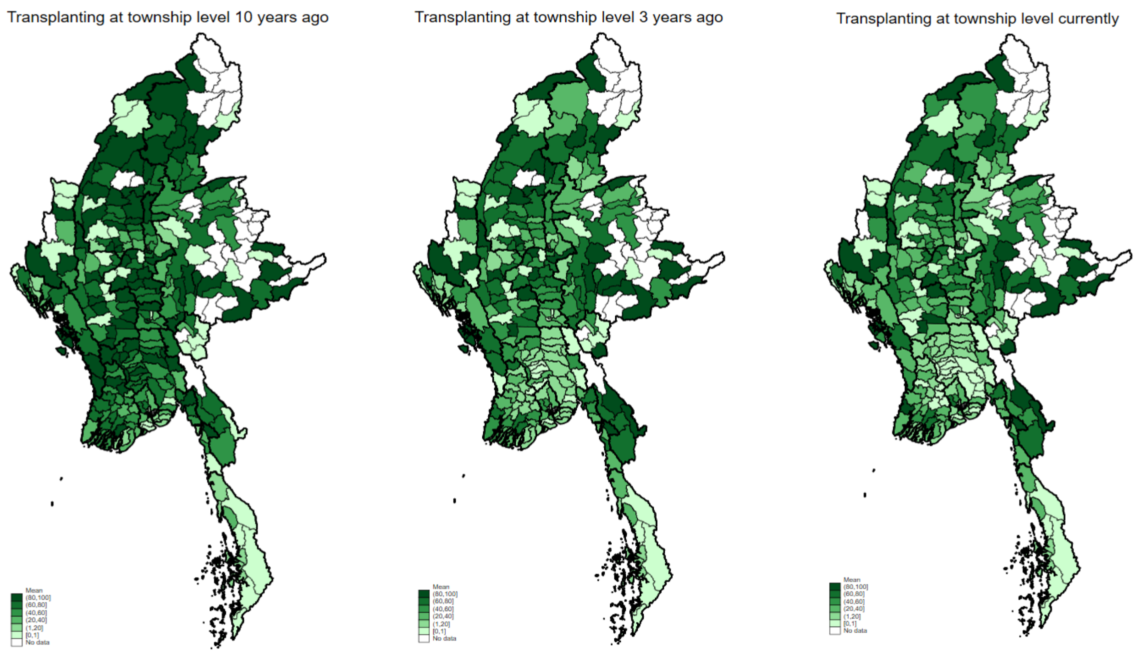
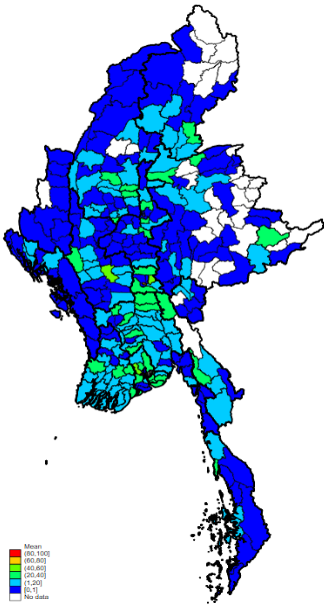
APPENDIX FIGURE

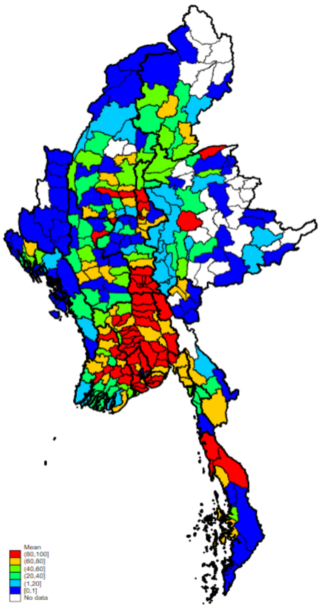
Figure A.1: Changes in the adoption of different agricultural technologies



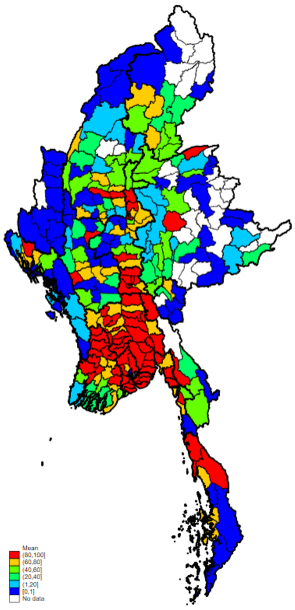
Combine Harvester Usage 10 years ago



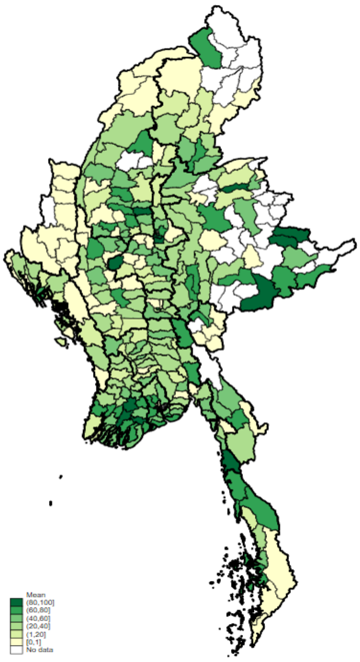
Combine Harvester Usage 3 years ago



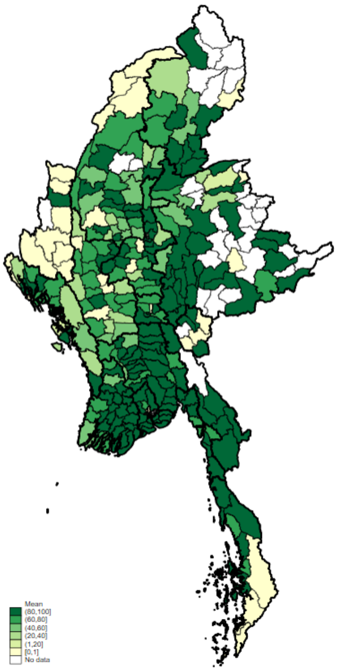
Current Combine Harvester Usage



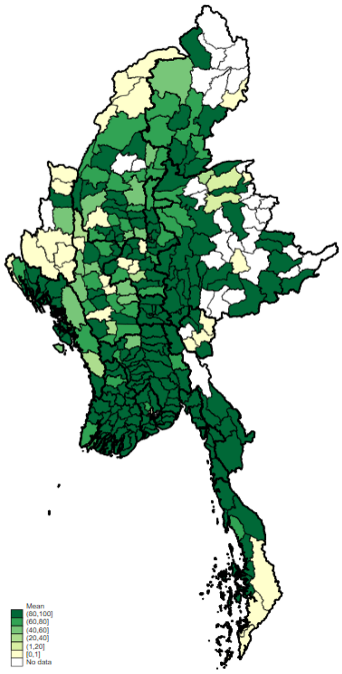
Tractor Usage 10 years ago



Tractor Usage 3 years ago



Current Tractor Usage



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