Slow adoption of mechanical rice transplanters in Nepal's cereal-based cropping systems:
reasons and recommendations for change

Gokul P. Paudel, Krishna P. Timsina, Saral Karki, Subash Adhikari, T. S. Amjath Babu, Timothy J. Krupnik

Cereal Systems Initiative for South Asia

Funded by

USAID FROM THE AMERICAN PEOPLE

BILL & MELINDA GATES foundation

Partners

NARC

CIMMYT International Maize and Wheat Improvement Center

IFPRI

IRRI

IWMI

CSISA COVID-19 Resilience Activity Partners

iDE

Slow adoption of mechanical rice transplanters in Nepal's cereal-based cropping systems:

reasons and recommendations for change

Gokul P. Paudel[1], Krishna P. Timsina[2], Saral Karki[1], Subash Adhikari[1], T. S. Amjath Babu[1], Timothy J. Krupnik[1]

[1]International Maize and Wheat Improvement Centre (CIMMYT)

&

[2]Nepal Agricultural Research Council (NARC)

Khumaltar, Lalitpur, Nepal

*Correspondence: g.paudel@cgiar.org

Cereal Systems Initiative for South Asia

Nepal Agricultural Research Council

The CSISA Nepal Covid-19 Response and Resilience Activity

Intensive cropping systems that include rice, wheat and/or maize are widespread throughout South Asia. These systems constitute the main economic activity in many rural areas and provide staple food for millions of people. Therefore, enhancing the yield and productivity of cereal production in South Asia is of great concern. Simultaneously, issues of resource degradation, declining labor availability and climate variability pose steep challenges for achieving the goals of improving food security and rural livelihoods.

The Cereal Systems Initiative for South Asia (CSISA) was established in 2009 with a goal of benefiting more than 8 million farmers by the end of 2023. The project is an exemplar of One CGIAR in action, and is led by the International Maize and Wheat Improvement Center (CIMMYT) and implemented jointly with the International Food Policy Research Institute (IFPRI), the Inernational Water Mangement Institute (IWMI) and the International Rice Research Institute (IRRI). Operating in rural 'innovation hubs' in Bangladesh, India and Nepal, CSISA works to increase the adoption of various resource-conserving and climate-resilient technologies, and improve farmers' access to market information and enterprise development. CSISA supports women farmers by improving their access and exposure to modern and improved technological innovations, knowledge and entrepreneurial skills. CSISA works in synergy with regional and national efforts, collaborating with myriad public, civil society and private-sector partners.

CSISA's Goals

- Facilitate the widespread adoption of resource-conserving practices, technologies and services that increase yields with lower water, labor and input costs.
- Support mainstreaming innovations in national-, state- and district-level government programs to improve long-term impacts achieved through investments in the agricultural sector.
- Generate and disseminate new knowledge on cropping system management practices that can withstand the impacts of climate change in South Asia.
- Improve the policy environment to facilitate the adoption of sustainable intensification technologies.
- Build strategic partnerships that can sustain and enhance the scale of benefits accrued through improving cereal system productivity.

With a new investment in the CSISA program, the USAID Mission in Nepal is supporting CSISA to rapidly and effectively respond to the threats posed by the COVID-19 crisis that undermine the recovery and sustained resilience of farmers in the FtF Zone of Nepal. This Activity includes Texas A&M University, Cornell University, and International Development Enterprises (iDE) as core partners. Activities involve two inter-linked Objectives that address CSISA's strengths in core areas needed to assist in COVID-19 response and recovery over an18 month period (From July 2020- December 2021). The ultimate goal of the CSISA COVID-19 Resilience Activity is to develop mechanisms to support longer-term resilience among smallholder farmers and the private sector – with emphasis empowering youth and overcoming challenges faced by women headed farm households. At the same time, the activity is assisting in efforts to increase smallholder farmers' understanding of, and capacity to protect themselves, from COVID-19. This is achieved through the dissemination of awareness raising messages on public health and by increasing economic opportunities for return migrants, smallholder farmers, and by encouraging resilience-enhancing irrigation.

Suggested citation:

Paudel, G.P., Timsina, K.P., Karki, S., Adhikari, S., Amjath Babu T.S., Krupnik T.J. 2021. Slow adoption of mechanical rice transplanters in Nepal's cereal-based cropping systems: reasons and recommendations for change. The Cereal Systems Initiative for South Asia (CSISA). Kathmandu, Nepal.

Printed in Nepal. Published in 2021

Acknowledgements:

This work was supported by the Bill and Melinda Gates Foundation and USAID through the Cereal Systems Initiative for South Asia (CSISA). The views and opinions in this document are those of the authors and do not necessarily reflect the Gates Foundation or USAID and shall not be used for advertising purposes. We will like to thank Frances Hunt for editing this report.

Table of contents

List of acronyms

CHC	Custom hiring center
DSR	Direct seeded rice
GoN	Government of Nepal
HYV	High yielding varieties
MoALD	Ministry of Agriculture and Livestock Development
MRTP	Mechanized rice transplanter
NAMEA	Nepal Agricultural Mechanization Entrepreneur Association
NARC	Nepal Agricultural Research Council
PMAMP	Prime Minister's Agriculture Modernization Project

1. Introduction

In 2014, the Government of Nepal introduced an agricultural farm mechanization policy, intended to expand farmers' access to mechanization in order to overcome the problem of acute labor shortages caused by out-migration (Gauchan and Shrestha, 2017). Although agricultural mechanization has a long-established history in Nepal, starting with the introduction of two- and four-wheeled tractors in the 1970s (Biggs and Justice, 2015), this formalization of mechanization policy provided an opportunity to both the public and private sectors to invest in and expand farmers' access to machinery.

The promulgation of this policy was viewed as an important step, and an indication of the government's commitment to keeping up with its neighbors in South Asia, including India and Bangladesh, both of which have their own strong agricultural mechanization policies. Nevertheless, labor out-migration and rising labor wages continue to be serious issues in the region, but particularly in Nepal, with farmers either not able to locate the labor they require for farm operations or to afford labor when it is needed (Maharjan et al., 2013a, 2013b). This compels farmers to delay crop management and other intercultural operations, aggravating agricultural productivity and profitability (Paudel et al., 2019). Policy responses in Nepal conversely favor the expansion of rural mechanization by providing subsidy and support schemes through different promotional programs.

Mechanization interventions which reduce the labor required for rice cultivation are critically important to making rice farming a productive and profitable enterprise (Bhandari et al., 2015; Dhital, 2017). Although around 1.5 million hectares of rice are cultivated in Nepal (MoALD, 2020), in 2020 the country imported around 900,000 tons of rice from India worth around NPR 22.24 billion (or USD 190 million) (GoN, 2020), an amount that is projected to increase in the future and which is a growing concern for agricultural policy makers. Timsina et al. (2021) has estimated the production and demand of rice for the coming 30 years and suggested that demand can be met through increasing current productivity by at least 27%–43% by 2030 and 42%–85% by 2050 based on different scenarios considering constant growth rate business as usual scenario, increase in production (due to adoption of improved technologies) and decrease in production (due to climate change effect), and change in demand. However, the current low productivity and the high cost of rice cultivation are partially attributed to this increasing dependence on imports (Khanal, 2018). It is essential, therefore, to identify the constraints acting upon Nepal's farmers and preventing the widespread adoption of mechanized rice transplanters (MRTPs), which are increasingly advocated by policy makers as a key solution to enhanced rice productivity. With such information, governmental programs can work together more effectively to encourage scale-appropriate mechanization together with development partners. Clarity on the performance of, and constraints to, the use of existing MRTPs in Nepal could also help to put in place measures to address the challenges that farmers using MRTPs face, which are at this point largely ignored.

The case for mechanization to improve efficiency in agriculture is evident in the uptake of scale-appropriate farm machinery among farmers in Nepal. Several mechanization options are already commercially available for weeding, harvesting and threshing (which are some of the most labor-intensive stages of rice cultivation[1]), with the adoption of over 4,000 reapers, 650 combine harvesters and thousands of threshers in Nepal's Terai (CSISA, 2020). These have significantly reduced harvesting and threshing costs, and reduced the drudgery and labor burden for members of farming households, especially women (Paudel et al., 2018).

However, casual labor is still widely used in the region to carry out rice seedling uprooting and transplanting activities, with limited technological options available for mechanical transplanting. Machine-sown, direct seeded rice (DSR) also is another available technology in Nepal's Terai that could serve as an alternative to MRTPs. DSR does not require seedling establishment and transplanting, and reduces the burden of rice nursery management. However, major barriers to its adoption have been identified (including access to seed drills, lack of DSR seed drill services, lack of farmers' technical knowledge needed to control weeds, and access to controlled irrigation). These have resulted in slow uptake and high rates of technology abandonment (D'Souza and Mishra, 2018).

MRTPs are therefore seen as an important technology, as their adoption can reduce the burden on farm labor of seedling uprooting and transplanting, reducing labor costs significantly (Farooq et al., 2001). For this reason, MRTPs are widely promoted and endorsed in public- and private-sector farm mechanization programs and campaigns, although few studies have yet addressed the disappointing dynamics of the lower-than-anticipated adoption and spread of the MRTP technology in South Asia.

1 Rice cultivation starts with nursery preparation, followed by uprooting the rice seedlings, land preparation, transplanting, weeding, basal fertilizer application, irrigation, split fertilizer application, insect and pest control, harvesting, threshing and post-harvest management. Around 40% of rice farmers in Nepal Terai use herbicides to control weeds, the adoption of which has been increasing in recent years (Datta, 1981).

Since 2009, government, research and development partners in Nepal have conducted several efforts to promote MRTP ownership and use in Nepal; to date, however, results have been limited.[2] At the same time, private sector investment in MRTPs as commercial products has been relatively lower than in other farm machinery (such as power tillers, four wheeled-tractors, threshers, reapers and combines). In Nepal, there are broadly three types of mechanization service which trigger farmers' use of machinery. Firstly, individual farmers or rural entrepreneurs may purchase and own their machines, using them on their own farm and at the same time renting out services to other farmers, thereby offering services on a fee-for-services basis. Two other widely promoted approaches to machinery availability and use are custom hiring centers (CHCs), and group ownership by farmers' cooperatives. As an example, Prime Minister Agricultural Modernization Project (PMAMP) has established more than 600 CHCs in Nepal in the last three years (Nepal Economic Survey, 2020). In both of these cases, the machine belongs to the community or members of semi-, informally or formally established social enterprises; they are considered collective assets and are primarily used by members through a community-established service charge. Most of these enterprises are supported by the government, mainly through subsidies, and indeed are currently the primary priority of government programs (Shrestha, 2021). These therefore differ from individual service providers, who invest their own money in machinery purchase and operate their own businesses.

In addition, the MRTP should be viewed differently from other machines that farmers hire or use such as the tractor (which is mostly used for non-agricultural purposes). In Nepal, the majority of MRTPs are imported and are expensive, and smallholder farmers with limited resources and financial capacity find them difficult to purchase. To overcome this, different models of service provision (e.g., rental services) are proposed by the research and development partners. However, even where rental services are available, MRTPs are only used during the rice transplanting season and remain idle for most of the time, increasing the time needed for the owner to break even and begin to see a return on their investment. Other issues contributing to the slow rate of expansion of MRTP use are the unavailability of spare parts needed for repair and maintenance, a lack of skilled operators, and the need for different types of nursery preparation method (Farooq et al., 2001).

It is however not within the scope of this study to suggest which model of service provision (that is, by individual owners to farmers, or shared among CHCs, cooperatives and groups) is the most effective. Rather, we have attempted to identify why the uptake of MRTPs has tended to be slow in Nepal, while also proposing potential pathways to address it. There are two approaches we could have taken to achieve this. The first would be to analyze the broader government policy on MRTPs and conduct qualitative case studies to assess its impact. However, this approach may not have provided sufficient information about the quantitative impact of technology on the broader population of farmers. As such, we conducted quantitative assessments by surveying existing MRTP owners and the farmers who have hired MRTP services to establish their rice crop. Comparatively few MRTPs have been adopted by farmers and service providers in Nepal's Terai, meaning it was possible to study a large proportion of available MRTP owners in our sampling frame and conduct a rapid short survey of farmers in an attempt to understand the factors hindering MRTP adoption. Understanding the perspective of farmers and users is the essential first step towards identifying the barriers to adoption and bottlenecks in the scaling-out of the technology. This study therefore aims to identify the issues and challenges faced by existing MRTP users and adopters in Nepal Terai. It is our view that understanding the social, economic, institutional and policy factors which facilitate the spread of MRTP need to be an immediate research priority to better inform future agricultural mechanization development policies.

[2] In early 2021, CSISA conducted an assessment to identify the numbers of rice transplanters in Nepal and found that only 42 MRTPs were operational in the country.

2. Materials and methodology

2.1. MRTP sampling

The Cereal Systems Initiative for South Asia (CSISA) project has been operational in Nepal since 2009, demonstrating MRTP technology to farmers and communities from the start. CSISA has conducted several MRTP market facilitation and technical training activities in partnership with the private sector, Nepal Agricultural Machinery Entrepreneurs' Association (NAMEA), input dealers, PMAMP and other development partners, in order to upscale MRTP ownership and use in Nepal. Importantly, each of these partners has also implemented their own programming to promote MRTPs independently, with an increased concentration in effort observable since the 2014 mechanization policy was introduced. For our survey, we obtained a list of MRTP owners from CSISA, PMAMP, Nepal Agricultural Research Council (NARC) and other projects. Our resulting data indicate that until 2021, a total of 42 MRTPs had been adopted by farmers in Nepal Terai. Our initial aim was to visit the individual farms and custom hiring centers to generate data and conduct a comprehensive assessment. However, due to COVID-19 travel restrictions, we relied on data collected by means of a telephonic survey. Of the 42 MRTP owners in Nepal, 22 were available, and we conducted the survey with these owners from April to May 2021. The survey questionnaire was designed to assess the price paid for the MRTP, the subsidy obtained, date of purchase, comparative advantage of manual vs. machine transplanting, farmers' experience of spare parts availability, and service/rental charges and area coverage. We aimed to understand the reasons for the slow adoption of the MRTP and identify the potential entry point for its upscaling. The sample included all types of MRTP owner: individual service providers, MRTPs owned by CHCs, groups and cooperatives, and others that were supported by development projects.

2.2. MRTP study area

Figure 1 presents the district-wise spatial distribution of the total 22 MRTPs surveyed, which were located across eight districts of Nepal Terai. In Sudur Paschim province we surveyed six MRTPs in Kailali and Kanchanpur districts (three in each district). Eleven MRTPs were in Lumbini province, of which the majority (seven) were in Bardiya district; three MRTPs were in Bagmati province. The phone numbers of just two MRTPs from Province 2 were available.

2.3. Analytical approach

The small sample size of MRTP owners and their farmer clients made it possible to provide an analytical narrative with simple yet informative summary statistics on the question of factors affecting MRTP adoption. Comparative assessments were made across different types of MRTP owner, regarding MRTP purchase prices, and costs and subsidies obtained by individual service providers, CHCs, groups and cooperatives. The resultant data were visualized graphically. Problems with MRTPs were next ranked based on those the users identified as most important and the frequency with which they were reported during surveys.

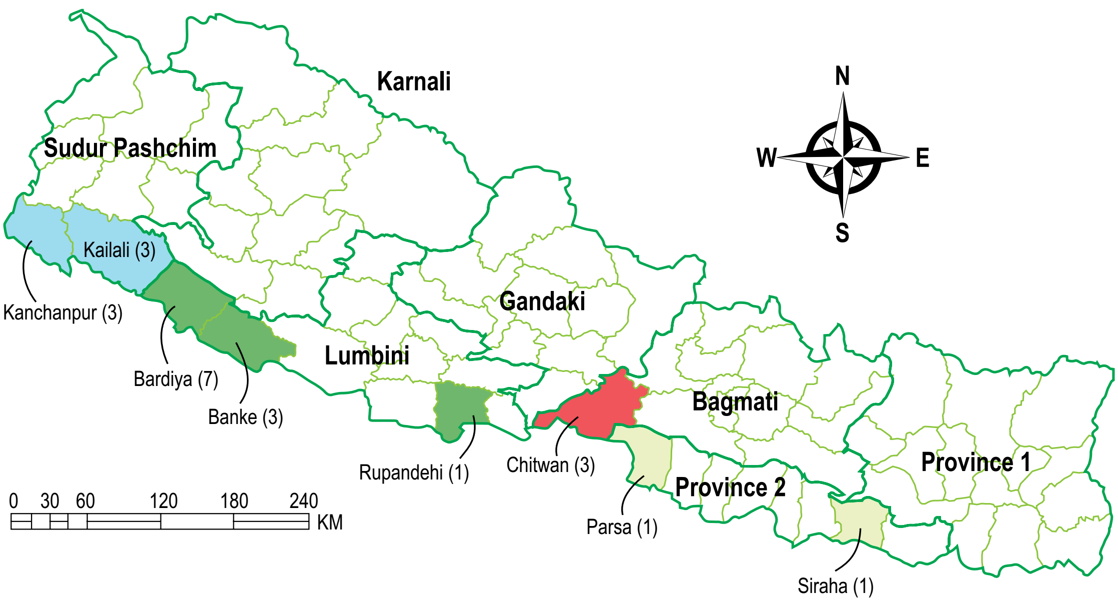

Figure 1. Districts in Nepal Terai, with the number of MRTPs included in the survey.

3. Results and discussion

3.1. General description and types of MRTP ownership

Of the 22 MRTPs surveyed, two were the walk-behind type and 20 were the ride-on type (Figure 2). The walk-behind MRTP transplants rice in four rows; the ride-on type transplants in four, six or eight rows, depending on the model[3]. These differences were reflected in the differing price of the machines, which was not always conducive to encouraging adoption, as section 3.2 makes clear. Three were purchased seven years ago and 15 between one and five years ago. Among the three MRTPs purchased seven years ago, two machines were purchased and handed over to their respective communities through a subsidy scheme, with the government contribution ranging between 50% and 100%. Only four were purchased without a subsidy, three of which were purchased by individual service providers. All 22 were supplied by import companies and their established channel of traders in the respective districts. Over two-thirds of owners reported purchasing the planter after attending an MRTP demonstration conducted by different projects and programs, including CSISA.

Of the multiple reasons given for purchase, the majority of farmers were motivated by the need to address the increasing labor shortage and to reduce the drudgery associated with rice seedling uprooting and transplanting. One-fifth of the MRTPs purchased were acquired merely in response to the provision of a government subsidy; however, the majority of owners acted out of motivation to mechanize rice farming. Those who did purchase an MRTP due to the subsidy provided mixed responses, as not all machines were consistently operated in each rice season. Among the 22 MRTPs, three were not functioning at the time of the survey; these had been purchased at least five years earlier. Figure 3 presents the categories of ownership of the MRTPs we surveyed.

The majority of MRTP owners we surveyed are farmers or communities who already own many other farm machines, with examples including four- and two-wheeled tractors, tractor attachments (cultivators, rotavators, harrows and drills), traditional levelers, irrigation pumps, combine harvesters, threshers and reapers, and others. Only three owners solely operated MRTPs and have no other farm machinery; two of these three are individual service providers and one is a member of the Kailali district farmer group. Our overall analysis shows that the majority of the MRTPs are owned by farmers who are familiar with farm machinery and interested in providing services to other farmers.

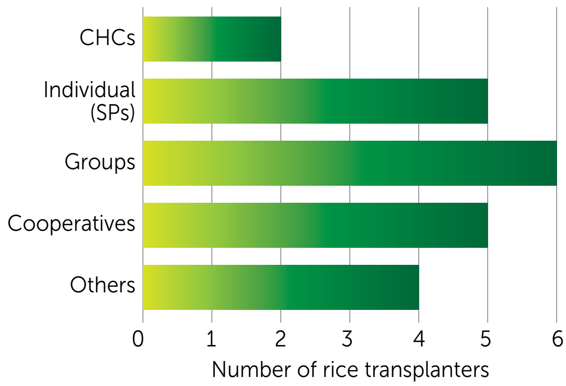

Figure 3. Rice transplanter ownership types. 'SPs' indicates mechanized rice transplanter service providers. 'Others' indicates a rice transplanter machine owned by a project (such as those implemented by NARC and/or the Rani Jamara Kulariya Irrigation Project).

[3] Of the 20 in our survey, two ride-on MRTPs transplanted in four rows, four of them in six rows, and 14 in eight rows.

Figure 2. A ride-on type MRTP (left) and walk-behind type MRTP (right) during the training and demonstration program organized by CSISA in western Nepal. Photo source (left: Peter Lowe/CIMMYT and right: Gokul Paudel/CIMMYT).

However, to gauge the sustainability of the use of MRTPs in providing services to farmers, it was necessary to analyze in more detail the patterns of MRTP investment and returns to the owner. This is presented in the section 3.3.

3.2. MRTP price and subsidy

This section discusses the price paid by the MRTP owners we surveyed and the level of subsidy they obtained. The cost of the MRTP ranged from NPR 450,000 (US$ 3,850) to NPR 2,090,000 (USD 17,900), with the average being NPR 687,000 (USD 5,872). The most expensive models of MRTP were manufactured in Japan and Korea, and the cheapest in China and India. Among those MRTPs surveyed, four transplanted in four lines and cost NPR 450,000 (USD 3,846)–NPR 900,000 (USD 7,692); four transplanted in six lines and cost NPR 525,000 (USD 4,487)–2,090,000 (USD 17,863). However, the remaining fourteen were eight-row MRTPs and cost NPR 450,000 (USD 3,846)–650,000 (USD 5,556) and these MRTPs were manufactured in different countries. One note in our observations was the high variability in the price for the same model of MRTP imported from the same country but sold by different traders. For example, in Kailali the same model of MRTP was purchased for NPR 450,000 (USD US$ 3,846) in one location and NPR 650,000 (USD US$ 5,556) in another, meaning that some local traders are charging an inflated price of over 40% for the same model. Such inconsistency, which we were unable to clarify the justification for in our study, could likely serve as a barrier to adoption – with or without subsidy. We recommend, therefore, that traders should aim to achieve profits from higher sale volumes rather than trying to obtain a high-profit margin by selling just a few MRTPs at an inflated price (although supportive policies may be needed to protect smaller machinery dealers who perceive the MRTP market to be risky).

In terms of subsidies, 18 (82%) of the MRTPs we surveyed obtained subsidies ranging from 50% to 100%, from different government and developmental programs. Among the three 100% subsidies provided to MRTP owners in our dataset, two were provided by Nepal's agricultural knowledge centers (AKCs) and Integrated Water Resource Management (IWRMP) project, while the third was provided by NARC and CSISA to an agricultural machinery testing and training center. One MRTP owner, an individual service provider, also obtained a 25% subsidy from the Rani Jamara Kulariya Irrigation Project in Kailali. The remaining 14 MRTPs were purchased with a 50% subsidy through different governmental programs (PMAMP, AKCs and others) which channel funds for buying equipment. Following purchase, these 14 machines were subsequently owned and operated by cooperatives, groups and CHCs. Our overall analysis reveals that subsidy – and the lack of clarity in standard subsidy terms and conditions, and variable subsidy offers – could be a major contributor to both the spread, but also the limited uptake of MRTPs in Nepal to date. In other words, without subsidy to offset the cost of machinery, very few individual farmers, cooperatives, farmer groups or CHCs could have purchased their MRTP. Our data also shows that only a very limited number of MRTP owners (3 out of 22) were willing to invest further to purchase new MRTPs with their own money, indicating farmers' low level of interest in investing in MRTPs. The low adoption of MRTP points towards a systemic problem that cannot be solved just by providing subsidies, and as such, mixed models that include efforts to extend bank and meso-level finance for MRTP purchase may be necessary, although most banks appear to be reluctant to support loans for non-conventional farm machinery at this time.

3.3. Rental charge, area coverage, and economic performance

As only 20 MRTPs were functional during the survey time, among which one had been purchased recently and not yet used and two were being used by group members without any service charge, we used the dataset of the remaining 17 MRTPs to estimate the current rental charge and season-wise area coverage. This information was used to assess economic performance of machinery used. We also compared the MRTP rental charge, area coverage and economic performance across the MRTP ownership types (that is, individual service providers, CHCs, cooperatives, groups, and others) by considering average costs and returns per season. As all MRTPs were used only for summer monsoon (Kharif season) rice cultivation, we used average income from service provision annual income to ascertain economic performance.

The average service/rental charge charged by the 17 MRTP owners was NPR 4,518 per hectare (Table 1). However, there was some variation in service/rental charge provided by the different service providers. The lower rental charges were offered by the CHCs (NPR 3,750 per ha) and the groups (NPR 3,937 per ha), while the rental charge was higher in cooperatives (at NPR 6,150 per ha) and MRTPs operated by other projects (NPR 4,750 per ha). Nevertheless, the individual service providers were offering the modest rental charge (NPR 4,000 per ha). These data suggest that individuals, as well as farmers who are members of CHCs or groups, are paying a modest cost to rent-in services, while farmers buying services from cooperatives pay higher rental charges.

Nonetheless, there was a dramatic difference across these ownership categories in terms of number of MRTPs operated and area coverage. MRTPs owned by CHCs and groups were used for 2.5 days and 6.5 days per season respectively, compared with those operated by individual service providers, at almost 23 days per season. The indication is that groups and CHCs do not use the MRTPs efficiently. A similar trend was also observed in area coverage. Over the same period of time, CHCs, cooperatives, groups and other types of MRTP owner provided rental services covering less than 11 hectares of land under rice cultivation, compared with MRTPs operated by individuals, who provided rental services covering 14 hectares of rice area (Table 1). Although MRTPs can be used for more than 45 days in a season, our results show that none of the 22 surveyed were being fully utilized, and in fact indicate that they are clearly being significantly under-utilized. There might be several reasons for this lack of effective use, and these are discussed in this report. Nonetheless, our overall analysis of service charges, area coverage, and number of days the MRTPs are operational suggests that with the modest service charge, the development and support of individual service providers could be a potential entry point to expanding MRTP use in Nepal.

In relation to economic performance, individual service providers reported having been able to obtain the highest returns compared with other MRTP owners, though these data need to be interpreted with care due to the small sample size. As area coverage and the number of days that MRTPs operated were highest for individual service providers, it is to be expected that the net return from them was the highest. However, it should be noted that these service providers were not granted a subsidy; instead, two of them invested their own capital and one has taken out loans from a formal bank[4], while all the CHCs, groups, cooperatives and others received a 50%–100% subsidy from different government programs. Our initial net benefit results indicate that MRTP owners may not be able to recover their investment if they do not manage to expand the area they cover and generate income from transplanting services (which therefore entails having more farmers as clients), as a low service area increases the payback period to several years, unlike most other less costly farm machinery. Our provisional results also suggest that the currently subsidized CHCs, cooperatives, groups and others operating MRTPs are unlikely to be sufficiently economically and technically efficient. Conversely, our results also suggest that the higher investment made by service providers has driven them to expand the area that they provide services, to obtain the greatest possible advantage from their MRTP ownership. In this light, the apparent merits and constraints associated with the start of MRTP adoption in Nepal are described in the next two sections.

[4] We did not ask which bank he used to take the loan to purchase the MRTP, as starting to explore bank loan details might deviate from the main context of the survey.

3.4. Benefits of MRTPs

One of the benefits of MRTPs compared to manual rice transplanting is the reduction in the amount of labor needed to uproot and transplant rice seedlings. There is also a reduction in drudgery associated with seedling uprooting and transplanting: this is particularly the case for women farmers (Gartaula et al., 2020). Other benefits associated with MRTPs are related to precision in transplanting, which makes it easier to control weeds and carry out other intercultural operations (Farooq et al., 2001). This may mean that this technology enhances productivity, to some extent, by facilitating crop establishment. However, there are also challenges associated with patchy crop stands due to unevenness in fields that have not been properly levelled, or from machine operator error.

However, the most highly perceived benefit among our sampled machine owners and farmers associated with the MRTP is the reduction in rice transplanting costs. The survey data show that on average, MRTP users transplant their rice for a cost which is less than NPR 4,518 per hectare, while using human labor to transplant the same field would cost around NPR 12,000 per ha (Figure 4). Our data shows that with the average labor wage rate of NPR 600 (US$ 5.13), a total of 20 laborers are required to uproot and transplant rice in one hectare of land. Therefore, MRTP use reduced the number of laborers needed and the total cost of rice transplanting. Some of the MRTP owners surveyed mentioned additional hurdles associated with the technical aspects of MRTP nursery establishment and management; as seedlings are raised in specialized nurseries, however, the over 60% reduction in transplanting cost was the major economic benefit that farmers appear to have obtained.

Table 1. Service charge, area coverage and no. of days MRTP used across owner's categories.

	No. of years of purchase	Total MRTP cost† (NPR)	Service charge (NPR/ha)	Total area covered (ha/season)	Number of days used (days/season)	Gross return (NPR/season)
CHCs	2.5	450,000	3,750.0	2.3	2.5	8,750.00
Cooperatives	2.2	1,146.000	6,150.0	2.6	4.6	15,990.00
Groups	1.8	513,750	3,937.5	10.8	6.5	42,328.13
Individual service providers	2.7	700,000	4,000.0	14.0	22.7	56,000.00
Others‡	4.0	533,333	4,750.0	2.2	5.7	10,450.00
Average	2.6	668,617	‡4,517.5	6.4	8.4	26,703.63

† Average values without taking any subsidy into account; these values are only for Kharif season rice production.

‡ MRTPs owned by the project, such as those implemented by NARC and the Rani Jamara Kulariya Irrigation Project (GoN). All values are the average of the samples across different ownership categories. Exchange rate: USD 1 = NR 117, as of May 2021.

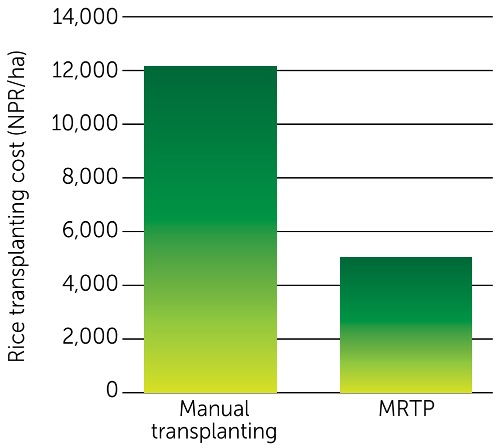

Figure 4. Comparative advantage of the MRTP over manual transplanting for rice farming in Nepal Terai. Source: CSISA phone survey, January-March 2021.

Beyond the economic benefits, some current MRTP owners suggested the important effect of overcoming labor shortage problems that are increasingly a concern in Nepal. Traditionally, rice is transplanted using human labor, but this has become increasingly scarce in recent years in rural Nepal due to labor out-migration (Khanal, 2018; Maharjan et al., 2013a; Paudel et al., 2018). Adopting the MRTP mitigates this. Some owners also suggested that MRTP use facilitates better weed management and improves the efficacy of harvesting machines (e.g., reapers, combiners). This is because the MRTP transplants rice in lines, facilitating the use of mechanical weeding machines (e.g., cono weeders), many of which are suitable to be used in the spaces between these lines[5]; harvesting using reapers is also easier. Some MRTP owners also stated that the stricter line sowing of rice enabled them to improve fertilizer broadcasting as it was easier to walk between crop rows in the field. Finally, the majority of the MRTP owners in our survey highlighted a reduction in the farm drudgery and the management of the labor shortage as important benefits associated with MRTP use.

3.5. Constraints of MRTP use

Users and owners reported several problems with MRTP use. Around 27% (n = 6) of MRTP owners had experienced difficulties in raising rice seedlings and nursery management, identifying this as a primary constraint to MRTP adoption (Table 2)[6]. Farmers generally do not use precision land-leveling methods in Nepal Terai and unleveled plots make crop standing patchy. An alternative locally modified method of raising seedlings could also avoid the cost of MRTP trays[7]. However, raising seedlings in trays can, according to the perceptions of some of our study respondents, result in the wastage of some seedlings. Also, most rice in Nepal is grown in the *Kharif* season, when maintaining the required level of water in the soil for machine transplanting is difficult due to unpredictable monsoonal rainfall. A solution to these issues could be the development of seedling-growing or nursery enterprises, in which before the rice-growing season, farmers pre-order the particular variety of seedlings required to grow rice in their area, with the nursery enterprise providing quality grown, MRTP-ready seedlings based on farmer demand. This could help to encourage seedling enterprises while at the same time avoiding the issue that farmers voiced associated with the challenges of establishind these specialized nurseries themselves. However, for such an enterprise to take off, a large number of farmers need to begin purchasing MRTP services, indicating the proverbial ‘chicken and egg’ problem. Alternatively, MRTP owners could offer farmers HYV seedlings and bundle the cost with MRTP service costs. Women workers or women’s groups can be contracted for such nursery preparation, generating additional employment opportunities for women. Such arrangements are showing initial promise in Bangladesh (CSISA, 2021).

The second major issue reported by MRTP users relates to its price. This was not unexpected, as Nepal’s agro-machinery industry is underdeveloped, meaning that each type of MRTP is imported and their price is very high. However, as we have

Table 2. Major issues reported by MRTP owners and users in Nepal Terai

Issues	Frequency (no.)	Percentage (%)	Problem ranking†
Difficulty in raising seedlings and nursery management	7	32	I
MRTPs are prohibitively expensive	4	18	II
MRTPs are difficult to operate in small plots	3	14	III
Accessing spare parts when needed is difficult/impossible	3	14	III
MRTPs frequently sink into the puddled plot	2	9	IV
No problem faced yet	2	9	-
Difficulty in repair and maintenance	1	5	V
Total	**22**	**100**	

Source: CSISA survey, 2021. † Problems were ranked according to frequency of reporting.

[5] This is important, as rice is a water-intensive crop and commonly susceptible to weeds.

[6] This problem is nuanced, as MRTP use requires a special type of nursery and particular care to raise the seedlings. The seedlings also need to be maintained at a certain height during transplanting and a couple of hours are required for the puddled soil to settle so that their roots reach the correct depth in the soil. The level of water in the puddled field otherwise will not allow the proper establishment of the seedlings, resulting in patchy crop standing.

[7] We assessed the costs of trays used in nursery establishment while using MRTP. The traders told us that the cost ranges from NPR 100 to NPR 250 per tray. An estimated 100 trays are required to establish in 1 hectare of land with a rice transplanter, although trays can be used for multiple years and seasons.

seen from our survey data, the considerable price variability for the same model of MRTP sold at different machinery dealers results in price distortion. This situation likely results from the limited number of MRTPs sold in Nepal having prevented the establishment of equilibrium prices. Given this situation, more stable pricing could potentially reduce MRTP costs, and we suggest that at the policy level, price control regulations could potentially be beneficial, so that importers and traders observe a price ceiling for different types of MRTP, albeit one which at the same time offers a reasonable profit margin for machinery dealers. This could benefit both farmers and traders: traders would benefit through the increased volume of sales of the machine, which the farmer would purchase at a lower price point. Observation of a price ceiling could be made mandatory for all subsidized MRTP purchases. Other options include a reduction in import tariffs; however, the Government of Nepal is now charging only 1% custom duty for single machine imports, and so a further reduction in machine tariffs may not reduce the price substantially.

The next two issues reported by existing MRTP users related to the machine being difficult to operate in small fields (in which the machine must turn around repetitively) and the difficulty (or impossibility) in accessing spare parts. Average landholdings and plot size are diminishing in Nepal due to land fragmentation, and while this may require government intervention and policy measures to be resolved, in the meantime farmers could consolidate existing small plots, use machines and share the outputs based on their plot size. For this to work, however, an understanding of MRTPs among farming communities needs to be accelerated. Similarly, communities will need to have strong social structures and an ability to act collectively.

All agricultural machinery breaks down from time to time, especially that with many small and delicate moving parts like MRTPs. Although spare parts may appear to be a technical issue, ensuring that MRTP owners and operators can access spare parts is, however, a policy- and market-related issue. The Government of Nepal currently charges a 1% tariff to import a complete MRTP; however, with the importation of spare parts this rises to around 35%, making most importers reluctant to bring the spares needed for repairs into the country. This results in serious and long-term breakdowns and limits the ability of MRTP owners to deploy transplanting services effectively within the limited Kharif season time-window during which rice needs to be established. A reduction in the import tariff would address the issue by motivating importers, increasing farmer access to the spare parts they need. Developing local light manufacturing capacity to produce key spare parts might also be a sustainable option. In either case, programs wishing to encourage MRTP use in Nepal need realistically to address these constraints, as the current focus on ensuring imports of whole machines – with no consideration of the spare parts needed to maintain them – results in broken machines that are not used and are at times abandoned.

Several other issues were reported by existing MRTP owners and users, in particular, the machine sinking into the puddled field (this is especially the case with the ride-on type of MRTP), problems with floatation and lack of traction to move across the field with lighter transplanter models, difficulty in transplanting in clay soil, difficulties with repair and maintenance, frequent wear and tear (such as the breaking of the metal 'fingers' that handle seedlings) requiring spare parts, a lack of skilled operators, patchy crop standing due to unleveled plots, and difficulty in transportation. We suggest that machine-related issues can be addressed through improved operator training, developing women's groups trained in nursery preparation, and developing the capacity of local mechanics, in addition to the need for significant improvements in aftersales services by machinery traders to improve product stewardship. However, other issues, such as the sinking of some MRTPs into the field, are complex and farmers should choose the appropriate machine at the time of purchase by assessing the types of field they anticipate transplanting in. Combined with enhanced training for machine transplanting, careful purchases which consider soil and hydrological field conditions could help reduce challenges in operation. Dealers can and should be trained to support farmers in this selection procedure. Moreover, although a few MRTP users reported an increase in productivity, others reported reductions in yield due to patchy crop stands. It should be noted that the MRTP is not necessarily a yield-enhancing technology (Farooq et al., 2001); rather, it is a labor- and cost-saving technology, and can facilitate other crop management practices such as weeding, harvesting and other intercultural operations, which together may increase productivity.

4. Major reasons for slow adoption

This section discusses the reasons for the slow adoption of MRTPs in cereal systems in Nepal Terai, based on our inferences from the survey. We also present possible solutions to each problem.

Cost.

Our survey results show that the MRTP is expensive in Nepal, potentially discouraging smallholder farmers with limited resources and financial constraints from purchasing it. While MRTPs are imported, farm machinery needs to be affordable to assure resource-limited farmers – which comprise the bulk of the farming population in the Terai (Takeshima, 2017a, 2017b) – can afford purchase. We found the average market price of this technology to be around NPR 687,000 (USD 5,890) that makes the payback period longer. In fact, farmers' investment may never be recovered fully until this technology is linked with sustainable business models ensuring larger area coverage, thus reducing the long payback period. The current government subsidy program primarily targets CHCs, cooperatives and farmers' groups. On the face of it, providing subsidy to promote collective ownership for community benefit appears just and reasonable. However, our preliminary data suggests that collectively owned MRTPs are neither sustainably used or economically efficient. We therefore suggest that government programs undertake further study and correct the performance incentives in collective ownership, or alternatively target individual service providers by linking them with the formal banking sector to obtain credit, which can also be mixed with subsidy programs to lower investment costs. Initiatives to expand MRTP service provision coverage in order to overcome the high cost of this technology are similarly warranted. The potential benefits will be two-fold: farmers will benefit from the provision of rental services at costs lower than hiring manual labor for transplanting, and individual service providers can run their mechanization services as an enterprise generating profits. This win-win scenario could have the added benefit of attracting youth involvement in agricultural mechanization and agriculture more generally.

Technological problems.

Our survey results suggest that several technological problems exist among the MRTPs currently operating in Nepal. The indication is that some models of MRTPs are not fit for purpose, which could be a second reason for slow adoption. Issues include the need for unique nursery and seedling management methods, challenges of operation in flooded field crop conditions, patchy crop establishment, the need for leveled plots, and frequent wear and tear, creating a need for scarce spare parts. We suggest that, given the objective of farmers and the government to expand MRTPs in Nepal, the selection of the most appropriate model of MRTP, while testing these imported technologies at the NARC training and testing centers, should be done before the technology reaches the market and the farmer's field. Conversely, models of public-private partnership in which companies collaborate with NARC to test equipment and certify it as suitable for a range of farming conditions is desirable. There are several models of MRTP available in East Asian countries, and importing the right model and conducting proper testing of these machines could help to resolve some of these technology-related problems. In addition, some farmers reported issues related to a lack of technical knowledge in repair and maintenance; these can be resolved through the right training programs and extended product stewardship and aftersales-services programs implemented by importers and dealers. Many projects and programs have started capacity development of local mechanics, and this activity could be linked to these projects/programs to solve any MRTP technical knowledge gap.

Unavailability of spare parts.

Another reason for the slow adoption of MRTP is the lack of spare parts available in local markets. Without these, existing machines cannot be repaired, which in turn affects the returns from the technology and limits its adoption. Our survey found several MRTPs had been abandoned due to a lack of spare parts. The indication is that this issue is an immediate priority if MRTP use and overall farm mechanization is to be expanded in Nepal. To identify a possible way to address this issue, we engaged in discussions with Nepal Agricultural Mechanization Entrepreneur Association (NAMEA), which indicated that its reluctance to import spare parts resulted from the high customs duty (that is, the high import tariff). Current government policy suggests over a 35% tariff for spare parts, compared with a 1% tariff for complete MRTPs when they are imported. As a result, the private sector is discouraged from importing spare parts, which are expensive in local markets because of the high tariffs charged. If the government's strategy is to upscale MRTPs in Nepal, policies need to be reconsidered that make spare parts easily available, starting with adjustments in tariff costs. An alternative, sustainable option could be to develop the country's light engineering capacity to manufacture key spare parts locally, a subject that deserves considerable further attention.

Small landholdings.

Most farming technologies require a minimum field size for successful operation. For example, large machines operating in small fields have to frequently turn around, which makes their operation challenging and limits technology adoption. In Nepal, the average farm size is shrinking, and fields are scattered in many parcels. To address this, several scale-appropriate farm machines are available in the market and farmers should be guided to select the technology appropriate to them and the size of their plot. At the same time, if farmers in Nepal are willing to adopt the larger MRTP machines, a potential solution to the issue of small, disparate plots could be land consolidation and land pooling. Land consolidation and pooling strategies however first need the development of understanding at the community level, and farmers would need to agree on a common crop and usually which variety to grow in certain locations or blocks, with the outputs shared based on their plot size or area. This would not only facilitate and increase the adoption of MRTPs but also the adoption of several other farm machines such as laser land levelers, seed drills and combine harvesters. Such strategies however require considerable social cohesiveness and coordination, which is often challenging to maintain.

Existing cropping systems.

Unlike rice-rice cropping systems in some countries of East and South Asia (e.g., Bangladesh), the Kharif season rice in Nepal currently occupies an area of over 99% of arable land (although Nepal's expanding spring season rice is the focus of considerable policy attention). The limited use of MRTPs for only one season (that is, during Kharif) means that purchasers are not easily able to generate sufficient income to break even in short time periods, which again affects adoption. To expand MRTP use in Nepal, expanding the use of MRTPs for winter and spring season rice could therefore be a potential cropping system-level solution, although most winter rice is grown primarily in eastern Terai, and spring rice cropping remains quite limited in the area. However, using the MRTP for two or three seasons a year would improve the economic returns from the technology and substantially reduce the payback period. This could attract additional investment to this technology from the public and private sectors.

Current government policies.

Some government policies in Nepal appear to be linked to the slow adoption of MRTPs. Principally, current subsidy policies are unfavorable to individual firms and service providers, as they target CHCs, cooperatives, and farmers' groups. However, without strong social pressure and cohesion, a lack of performance incentive can exist in group ownership, appearing in this case to lead to inefficiencies and lower returns. This seems evident from the subsidy allocation to groups, CHCs and cooperatives, while individual firms and service providers are excluded from the subsidy programs. For example, our findings show that none of the individual MRTP service providers were included in the subsidy programs (except for one, who obtained a 25% subsidy from the Rani Jamara Kulariya Irrigation Project in Kailali), while all the CHCs, groups and cooperatives were provided with a subsidy of up to100%. This focus on the collective and communal approach discourages private firms and entrepreneurial individuals from investing in agricultural mechanization, including MRTPs. To expand investment, policy makers could therefore consider the integration of individual service providers into their programs and devise policies to encourage groups to use the subsidized machines more efficiently. This could potentially motivate both individual and collective actors, whose involvement could expand the adoption of MRTPs in Nepal. Our preliminary analysis also shows that, despite not getting any support from government programs, individual service providers were the most efficient actors currently renting out MRTP services to other farms.

5. Conclusion and recommendations

This study has examined the status of the MRTP in Nepal Terai. We identified the potential drivers responsible for the slow adoption of MRTPs and suggested solutions to contribute to overcoming constraints in Nepal. Although our dataset is small, it does comprise half the total population of MRTP owners in the entire country, and hence represents the views of existing MRTP owners and users. Our results highlight the substantial benefits associated with MRTP use, the most important being the reduction in rice transplanting and seedling uprooting costs, cost of hired labor, and farm drudgery. At the same time, several issues emerged which contribute to the slow adoption rate of the MRTP in Nepal Terai. In light of these, we recommend:

- Incorporate individual service providers or firms into government programs by facilitating their access to subsidized credit.
- Develop financial instruments to allow banks to lend to individuals and groups to purchase MRTPs in ways that leverage partial subsidies but that cover remaining cash costs.
- Correct performance incentives that currently apply to group ownership (including CHCs and cooperatives) of the MRTP and refocusing incentives on individual entrepreneurs.
- Expand rice cultivation in the winter and spring seasons.
- Where farmers exhibit a high degree of social cooperation and cohesion, consider consolidating small parcels of land into larger plots (blocks).
- Offer initial incentives (such as vouchers) to farmers to encourage them to adopt MRTPs and conducting research for further recommendations.
- Encourage women's groups and youth to engage in nursery seedling raising as an enterprise activity.
- Increase spare parts availability in the local market through reduction in import tariffs and supporting to the local light engineering sector.
- Reduce MRTP price variability through establishing a price ceiling.
- Provide technical capacity for operators, mechanics and MRTP owners, ideally through aftersales-services and product stewardship programs implemented by machinery dealers and importing companies.
- Facilitate the testing and selection of appropriate MRTPs to fit the rice systems in Nepal as potential entry points for mechanical MRTPs intensification in cereal systems in Nepal.

6. Acknowledgments

This research was conducted as part of the Cereal System Initiatives for South Asia (CSISA) project in Nepal, funded by United States Agency for International Development (USAID) and Bill & Melinda Gates Foundation and implemented by researchers at International Maize and Wheat Improvement Center (CIMMYT) and Nepal Agricultural Research Council (NARC) as part of the CSISA COVID-19 Resilience Activity supported by the USAID Mission in Nepal. We would also like to thank Pralad Phuyal for conducting the telephone surveys, Sumona Shahrin for improving the figures, and Peter Lowe/CIMMYT for the cover page photograph. The views expressed in this working paper are those of the authors and do not necessarily reflect the views of USAID, Bill & Melinda Gates Foundation, CIMMYT or CSISA.

References

Bhandari, N.B., Bhattarai, D., Aryal, M., 2015. Cost, production and price spread of cereal crops in Nepal: A time series analysis. MoAD, Lalitpur, Nepal.

Biggs, S., Justice, S., 2015. Rural and agricultural mechanization: a history of the spread of small engines in selected Asian countries. IFPRI Discussion Paper 01443, Development Strategy and Governance Division. International Food Policy Reserach Institute, Washington, DC.

CSISA, 2021. Cereal Systems Initiative for South Asia – Mechanization Extension Activity (Six-monthly report) October - March 2021. Bangladesh.

CSISA, 2018. Cereal Systems Initiative for South Asia. Phase III. Semi-annual report. International Maize and Wheat Improvement Center (CIMMYT), Kathmandu, Nepal.

D'Souza, A., Mishra, A.K., 2018. Adoption and abandonment of Partial conservation technologies in developing economies: The case of South Asia. Land Use Policy 70, 212–223. https://doi.org/10.1016/j.landusepol.2017.10.015

Datta, S.K. De, 1981. Principles and practices of rice production. International Rice Research Institute (IRRI).

Dhital, B., 2017. Economy of production and labor requirement in major field crops of Kavre, Nepal. International Journal of Environment, Agriculture and Biotechnology 2, 350–353.

Farooq, U., Sheikh, A.D., Iqbal, M., Bashir, A., Anwar, Z., 2001. Diffusion Possibilities of Mechanical Rice Transplanters. International Journal of Agriculture & Biology 17–20.

Gartaula, H., Sapkota, T., Khatri-Chhetri, A., Prasad, G., Badstue, L., 2020. Gendered impacts of greenhouse gas mitigation options for rice cultivation in India. Climatic Change 163, 1045–1063.

Gauchan, D., Shrestha, S., 2017. Agricultural and rural mechanisation in Nepal: status, issues and options for future, in: Mandal, S.M.A., Biggs, S.D., Justice, S.E. (Eds.), Rural Mechanisation. a Driver in Agricultural Change and Rural Development. Institute for Inclusive Finance and Development, Dhaka, Bangladesh. pp. 97–118.

GoN, 2017. Foregin trade statistics of Nepal. Annual trade data for fiscal year 2017. Trade and Export Promotion Center. Ministry of Industry, Commerce and Supplies. Kathmandu, Nepal.

Khanal, U., 2018. Why are farmers keeping cultivatable lands fallow even though there is food scarcity in Nepal? Food Security 10, 603–614.

Maharjan, A., Bauer, S., Knerr, B., 2013a. Migration for labour and its impact on farm production in Nepal. Working Paper IV. Center for the study of labor and mobility. Kathmandu, Nepal.

Maharjan, A., Bauer, S., Knerr, B., 2013b. International migration, remittances and subsistence farming: Evidence from Nepal. International Migration 51, 249–263.

MoALD, 2020. Statistical information on Nepalese agriculture. Ministry of Agricultural and Livestock Development, Kathmandu, Nepal.

Nepal Economic Survey, 2020. Government of Nepal, Ministry of Finance. Singhdurbar, Kathmandu, Nepal.

Paudel, G., Shah, M., Khandelwal, P., Justice, S., McDonald, A., 2018. Determinants, impacts and econmics of reaper adoption in the rice-wheat systems of Nepal. Agricutlure Development Jourunal 14, 63–72.

Paudel, G.P., KC, D.B., Rahut, D.B., Justice, S.E., McDonald, A.J., 2019. Scale-appropriate mechanization impacts on productivity among smallholders: evidence from rice systems in the mid-hills of Nepal. Land Use Policy 85, 104–113.

Shrestha, M., 2021. Custom hiring centres a top priority for Nepali Provincial Government. ACIAR-SDIP. URL https://aciarsdip.com/latest-news/2021/2/8/custom-hiring-centres-a-top-priority-for-nepali-provincial-government. Retrived July 11, 2021.

Takeshima, H., 2017a. Custom-hired tractor services and returns to scale in smallholder agriculture: a production function approach. Agricultural Economics 48, 363–372.

Takeshima, H., 2017b. Overview of the evolution of agricultural mechanization in Nepal. IFPRI Discussion Paper 01662, Development Strategy and Governance Division. International Food Policy Research Institute, Washington, DC.

Timsina KP., Gauchan D., Gairhe S., Subedi SR., Pokhrel BB., Upadhyay S., Joshi KD.,2021 (Forthcoming). Can Nepal produce enough rice to meet future demand?. In the proceeding of the National workshop on "Modernization of Agriculture for a Prosperous Nepal" held on 4-5 Ashad, 2078 (June 18-19, 2021) organized by Department of Agriculture (DoA) and Nepal Agriculture Federation (NAF).

International Maize and Wheat Improvement Center (CIMMYT)
CIMMYT-Nepal, Agriculture Botany Division – 1st floor, NARC
Research Station, Khumaltar, Lalitpur, Nepal

Funded by

USAID FROM THE AMERICAN PEOPLE
BILL & MELINDA GATES foundation

CSISA

Partners

NARC
CIMMYT International Maize and Wheat Improvement Center
IFPRI
IRRI
IWMI