

RESEARCH ARTICLE

EMERGING TECHNOLOGICAL INSIGHTS, HOTSPOTS CHALLENGES AND FUTURE DRIVING PATHWAYS FOR WHOLE PROCESS MAIZE MECHANIZATION IN NEPAL

Shailendra Khatri*, Shreemat Shrestha

National Agricultural Engineering Research Centre, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Bagmati, Nepal
Corresponding Author E-mail: shailenkhatri@yahoo.com

This is an open access article distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

ARTICLE DETAILS

Article History:

Received 06 September 2023
Revised 18 September 2023
Accepted 14 October 2023
Available online 16 October 2023

ABSTRACT

Globally, mechanization has been recognized as a key means to increase the agricultural production and modernize the agriculture. Although the use of improved varieties has increased substantively since a decade, the use of land and labor saving technologies specifically mechanization and adoption of improved management practice, has lagged behind in Nepal. Thus, this study explores the current maize production status, past and present developmental effort on mechanization, and provides outlook on the currently available tools, equipment and machines for whole process maize mechanization (an array of available technologies from land preparation to post-harvest operation). Finally, we pointed out the mechanization hindering factors and gaps, and suggested the future driving paths along with potential emerging technologies that can have impact on future maize mechanization of Nepal. Though, there has been increase in the use of machines in Nepalese agriculture mostly in tillage and shelling for maize, yet use of machines is very limited in rest of the operations (for example, harvesting). To succeed the mechanization roadmaps, it is necessary to unify research and development efforts on need based technologies referring agro-ecological, socioeconomic and technical conditions; strengthen extension and credit services for adaptation and investment; formulate or implement quality inspection policy/program effectively; provide constant technical backstopping for institutional and community capacity building; upsurge awareness; establish provincial level mechanization centre and local level mechanization unit immediately; create community or contract farming schemes; promote custom hiring in business model considering the local level need; provide training, education and subsidies to the deserving farmers irrespective of their political attachment; assure timely availability of genuine spare parts and maintenance services; and form public-private partnerships for sustainable agricultural mechanization.

KEYWORDS

Agricultural Mechanization, Driving Pathways, Maize, Whole Process, Nepal

1. MAIZE STATUS IN NEPAL

Around the world, maize is a multifaceted crop grown in diverse agro-climatic conditions for food, fodder, feed and industrial purpose. In the context of Nepal, maize being one of the principal food crops of the majority of the hill people shows an ample character in nurturing the livelihood and nutritional requirements of people. Considering the governmental statistical data, maize is the second most important cereal crop after rice both in terms of area and production. Cereal crops have a total area of 3,465,455 ha with 3.21 mt/ha productivity and 11,118,512 mt production out of which maize contributing to production of 2,997,733 mt (26.96% in total edible cereal grain production in Nepal) with 979,776 ha cultivation area and 3.06 mt/ha productivity during 2020/21 (MoALD, 2022). Among the provinces, Madesh has the highest productivity (3.48 mt/ha) of maize while the lowest (2.71 mt/ha) in Sudurpashchim (Table.1). Compared to year 2005, the area and production was increased by 15.2% (129884 ha) and 74.6% (1281691 mt) respectively in 2021 (MoALD, 2022; KC et al., 2015). Moreover, the increased in maize productivity was 59.70% (1.2 mt/ha) (from 2.02 mt/ha in 2005 to 3.48 mt/ha in 2021). Even though statistical data shows increase in maize area, production and yield over decades, maize yield in Nepal is still lower than potential yield of 6.7 t/ha (experimental yield) and attainable yield of about 5.7 t/ha presently (KC et al., 2015). Despite those facts, the

contribution of the cereal crops commodities amounts to almost 25% of agriculture GDP (33% in nation GDP), of which maize contributes 6.79%.

Maize is cultivated under sub-tropical to cool temperate climates under different cropping configurations. For instance, it is grown as a single crop or relayed with millet later in rainfed conditions during the summer (April-August). While, it is also grown in the winter and spring with irrigation in the terai, inner-terai, valleys, and low-lying river basin areas (Paudel et al., 2001). These days, cultivation of winter maize in eastern and central terai is increasing every year which can be an opportunity to upsurge the maize production in Nepal. Despite the increase in maize cultivation, the production seems still insufficient and Nepal imported maize (seed, grain and processed maize product) amounting 16.6 billion rupees annually from abroad to fulfill the soaring demand of consumer (Table.2). Considering the current import/export data scenario, the import substitution can only be done by increasing the productivity of maize by increasing land productivity, resource and input use efficiency through technology adoption and mechanization with the available shreveled land and farmer's economy (Kandel et al., 2021). Furthermore, there is tremendous opportunity of cultivating and producing maize in the country that could contribute to the national economy within its scope of grain and processed food demand in the changing socioeconomic contexts such as rapid expansion of poultry and feed industries in Nepal.

Quick Response Code



Access this article online

Website:
www.bigdatainagriculture.com.my

DOI:
10.26480/bda.02.2023.77.88

Table 1: Status of province-wise maize production scenario in Nepal for fiscal year 2020/2021 (MoALD, 2022)

S.N	Province	Total area (ha)	Total production (mt)	Productivity (mt/ha)
1.	Koshi	289,714	884,659	3.05
2.	Madesh	53,201	185,297	3.48
3.	Bagmati	206,391	691,437	3.35
4.	Gandaki	149,414	450,721	3.02
5.	Lumbini	150,179	429,792	2.86
6.	Karnali	85,684	233,390	2.72
7.	Sudurpashchim	45,195	122,438	2.71
	Total	979,776	2,997,733	3.06

Table 2: Imports and exports of maize by Selected Agricultural Commodities, Fiscal Year 2020/21 (MoALD, 2022)

Commodity Description	Quantity (Kg)	Import/export Value (NRs.'000)
Import		
Maize seed	12537089	851618
Maize (excl. seed)	578404416	15168816
Maize (corn) flour	73907	2823
Groats and meal of maize (corn)	1560176	57152
Other worked grains of maize (corn),nes	538102	22588
Maize (corn) starch	8558160	332026
Maize (corn) oil (excl. crude) and fractions, refined or not but not chemically mo (in litres)	50079	11510
Corn flakes	568444	160675
Export		
Maize (corn) flour	670	501

2. PROBLEMS OF MAIZE CULTIVATION

Maize production in Nepal is characterized by low levels of mechanization, i.e. heavy reliance on human muscles as the foremost source of farm power. The major problems face by farmers in maize cultivation includes lack of quality seed and fertilizer on time (compelled to buy seeds from neighboring countries on their own risk without any insurance), rainfall pattern, insect pests and diseases in maize field, low irrigation facilities, poor level of input use, lack of appropriate multi purposes tools and machines. Similarly, Nepalese agriculture is currently opposed with series of dares like ageing farmers, feminization of agriculture, farm labour scarcity (migration of youth and family to cities and foreign countries for non-agriculture employment), rapid urbanization (shrinking agricultural land), deprivation of natural resources, spiraling prices, and susceptibility to climate change. Traditional agriculture trend such as labour bartering work during major agricultural operations (mostly in tillage, weeding and harvesting) is very limited at present in villages. Agricultural laborers scarcity and increased wage rate due to high demand in peak cropping periods causes delay in crucial operations such as land preparation, sowing, inter-cultural operations and harvesting, which severely disturbs the timeliness of operations and crop yield. As a result, alteration to non-agricultural avenues for livelihood, increasing fallow land per year, untimely planting and harvesting, and decreasing agricultural productivity has changed the agricultural scenario of Nepal. These factors have created an increasing demand of mechanization and means to attract youth back to agriculture. In the aspect of these dares, the country need knowledge intensive transformational alteration in agriculture that combines advances in science and agricultural engineering with country's unique traditional knowledge to make agriculture more naturally resilient. Thus agricultural mechanization can be considered as a viable avenue to address many of the concerns arising due to shortage of agricultural laborers.

Thus, this paper aims to: (a) briefly describe the production status and associated problem in maize cultivation (b) reveal the past and present

developmental effort on agricultural mechanization in Nepal; (c) provides technological insights on the present availability and consequence of agricultural machines in Nepal; (d) finally, unveil the hindering dynamics of mechanization and future driving paths for enhancing mechanization of Nepal.

3. MECHANIZATION DEVELOPMENT OF NEPAL

Agricultural mechanization incorporates the use of technical and scientific knowledge (tools, implements and machines) into the field of agriculture to improve crop yields, land and labour productivity, and drive commercial agriculture. This involves a single or combination of human, animal or motorized power utilized simple and basic hand tools to more sophisticated and motorized equipment for land preparation, management and processing of crops. There is no doubt that mechanization can act as a mainstay of the present agricultural systems across the country when correctly applied. As the demand for maize is increasing, the productivity of land can be improved by increasing resource and input use proficiency through implementation of improved cultivation technology and inclusion of mechanization. In other words, intervention of whole process mechanization packages for crop is key to increase the yield and production.

In the past decade, the agricultural mechanization had been characterized by very low mechanization levels and lethargic growth although efforts to promote agricultural mechanization were done by government and some private interventions in limited way. Mechanization has been limited to land preparation particularly tillage work and partially shelling operations. Rest of the operations like planting and harvesting operations have been predominantly performed using manual labor. Whilst in past eras, promotion of mechanization had not been successful and received much criticisms because of easy availability of labour, limited demand for agricultural mechanization in crop cultivation, issues in capital investments and negative misconception such as labour displacement and monopoly on subsidies. As a consequence, introduction of new labour

saving machinery technologies such as tractor, mechanical planter, combine harvester and seed drill in Nepalese agriculture had chance of facing social repercussion. Since a decade, the shortage of local agricultural labour due to remaining of increased aged population in villages (youth migration to cities and abroad for better opportunities and employment), rising wages, and the declining interest of youth in farming has compelled farmers to go in alternatives of the labour demand which foster the demand for agricultural mechanization services. It is stated that the Department of Foreign Employment (DOFE) has issued over 4 million labor approvals to Nepalese workers in the last decade since 2008/09 for foreign employment (MoLESS, 2020). Such a transformation of agricultural labor can be regarded as a major driver for the prompt introduction of agricultural machinery in farming system of Nepal; however, smallholder farmers are incompetent to buy agricultural machines individually. Somehow, the establishment of a mechanization rental service, mechanization laws, and a massive government subsidy since new federal system, have enabled farmers to access these machines partially. Likewise, farm size, irrigation situation, credit and policy support also plays a role in farmers' decision to adopt agricultural mechanization services.

Mechanization of tillage operation in terai belt is already predominantly practiced with the proliferation of more affordable four wheel and two-wheel hand tractors (mostly 12 to 15 HP power tiller). But operation wise maize mechanization has been sluggish in Nepal although tractors were already introduced decades ago. The level of mechanization also seems uneven among regions (being higher in terai belt, lowland and gently sloping areas than in hilly areas with steep gradients), in crop-types (being higher in rice and wheat than in maize), and in agricultural operations (application in tillage is much higher than in harvesting and postharvest activities). However, at present, small tractors (mini tiller) are rapidly emerging as tillage mechanization tool in hilly regions. Until the promulgation of the agricultural mechanization promotion policy (AMPP) 2014 and Agricultural Development Strategy (ADS) 2015, agricultural mechanization was ignored and not encompassed in any policies and plans (Agricultural Policy 2004, Agriculture Perspective Plan 1995-2015, periodic plans-5/3 yearly plans, and annual budget programs). Formulation of AMPP has drawn a vibrant path for agricultural mechanization in Nepal and ADS has highlighted mechanization as a weighty input for enhancing agricultural production. After year 2008, there has been phenomenal growth in the number of tractors registered in Nepal. For instance, upto fiscal 2008/09 the total registered tractor was 45,496 and within a decade it increased more than twice times and reached to 1, 53,727 (2018/19). In addition, upto 2008, average annual registered tractor was around 2275 but within a decade that reached to more than 5100 per year signifying an increased level of mechanization (DOTM, 2022). The increase of power tiller sale could be due to the emerging private sector in import and sales of power tiller in Nepal and the bulk number of governmental subsidy programs after the AMPP 2014 and ADS 2015.

Regarding agricultural mechanization research, after the establishment of the Nepal Agricultural Research Council in 1991, Agricultural Engineering Division initially started to test, verify and promote imported agricultural machinery such as power tillers, seed cum ferti drill, reaper, rice transplanter, zero till drill, small tractors, etc. Since a decade, comprehending the farmer's agricultural problems, it has also prioritized research and training on agricultural machinery, and prototype development and later commercialized them through private workshops such as jab seeder, manual corn sheller, coffee pulper, seed cleaner, millet thresher, metallic monkey repeller, hand chaff cutter etc. Similarly, Agricultural Implement Research station (AIRS), Ranighat, Birgunj (a research wing of Agricultural Tool Factory (ATF)) was handed over to NARC after the privatization of ATF. Since then, AIRS is working on the testing and promotion of different imported mechanization technologies for maize, potato, rice, wheat and sugarcane in the terai belt of Nepal (AIRS, 2018). Moreover, increasing voices on poor quality of imported machineries in recent years, has enthused government to establish Agricultural Machinery Testing and Research Centre (AMTRC) as a new wing of NARC at Nawalpur, Sarlahi in 2018 to undertake machinery testing, quality control and standardization which still needed coordinated effort from related stakeholders for enhancing the centre performance and services.

Since a decade, research organizations and extension agencies are also prioritizing agricultural mechanization of smallholder farms of Nepal as most of the farming system is of subsistence type. As an impact, currently, farmers are using small machines such as chaff cutter, electric water pump, combine mill, maize sheller, manual winnowing machine, mini tiller, brush cutter with multi-function attachment etc. In the context of heavy machines, the farmers are using four wheel tractors with different attachment, precision planter, multi crop thresher, etc. Farmers are getting machines and tools with different subsidy schemes provided by different governmental and non-governmental organizations. Until AMPP, ADS and new constitution; machinery extension, training and subsidy program was mostly run by Directorate of Agricultural engineering (DOAE), Lalitpur (since 2004) and related District Agricultural Office in limited basis. After the promulgation of new constitution 2015 in Nepal, there seems significant progress in the mechanization promotional activities. The three tier level of government (Federal, Provincial and Local) emphasized and put mechanization activities on their program through subsidy schemes ranging from 50% to 85%. Primarily, most of the program of agricultural knowledge centre and municipalities were focused in purchasing and distributing of agriculture machineries and less focused in trainings and capacity buildings of farmers to operate those machineries. Now they slowly realized the importance of training and dissemination activities for effective implementation of mechanization activities. Moreover, the program duplication and inconsistency within the subsidy schemes provided by the different tiers of government to take credit in mechanization work is building a dispute and problematic working environment among stakeholders. In addition, the central government also prioritize dissemination and demonstration program through their extension wings such as DOAE (merged with Agribusiness Promotion and Market Development Directorate and renamed as The Center for Infrastructure Development and Mechanization Promotion in 2018), Department of Agriculture, and special project (PMAMP) etc. For instance, to upsurge the reach of mechanization to small and marginal farmers, DOAE had provided subsidy on agricultural machines and also in establishing community post-harvest centers and custom hiring centers in different region of Nepal. DOAE in collaboration with other stakeholders also conducting national agricultural mechanization exhibition in certain time interval (since 2014, five event were organized) to help promote mechanization. Similarly, PMAMP is also investing billion Nepalese rupees in the name of pocket, block, and super zones on mechanization, by the distribution of agricultural machinery and land pooling. Different stakeholders (local Agri machinery entrepreneurs and the private sector for example, Nepal Agriculture Machinery Entrepreneurs Association) also slowly started machinery demonstration, exhibition and promotion, as well as maintenance and repair services. The non-governmental organizations such as CGIAR centers (CIMMYT, IRRI etc.) are also contributing in Nepalese mechanization by accompanying their agriculture mechanization programs with their own schemes but partial alliance with the national research and extension system. Despite those positive attempts, still, there seems huge gaps in coordination among different stakeholders (especially research, education and extension wings) in the name of credit taking for mechanization activities.

The government implemented the credit facilities and insurance schemes through banks and insurance company. For example, the government has started providing agriculture insurance facilities (75-80% subsidy in insurance fee for the agricultural insurance to the farmers) since FY 2013/2014 (2070/71 BS). However, due to the low coverage of crop insurance, the insurance board has made it mandatory for non-life insurance companies to sell at least 5 percent in agro-insurance policies of their total policies in a year. Regarding agricultural loan, government is providing interest subsidy of 5 percent on loan for commercial agriculture farming. Various Nepalese bank and financial institutions, for instance, Nepal Bank Limited and Agriculture Development Bank have prioritized mechanization access to farmers by including agricultural mechanization and storage structure in their interest-subsidized agricultural lending sub sectors.

4. AGRICULTURAL TOOLS, EQUIPMENT AND MACHINES FOR MAIZE CULTIVATION

Table 3 shows the various agricultural implements used in different stages of farming starting from land development and seedbed preparation to the post-harvest operations of crop.

Table 3: Agricultural tools and machines used for overall agricultural operations in Nepal

S.N	Agricultural operations	Manual	Animal drawn	Power operated
1.	Land and seed bed preparation and tillage work	Hoe, Spade,	Traditional plough, Disc harrow, Metallic plow	Mini tiller, Power tiller, Tractor, Cultivator, Tractor levelers, Laser land leveler, Rotavator, Disc plough, MB plough, etc.
2.	Seeding and transplanting	Small kutto, Jab seeder, Push seeder, Dibbler, Planter	Metallic plough, Seed cum fertilizer drill	Seed Drills, Planter, Rice transplanter, Happy seeder, dribbler, potato planter
3.	Fertilizer broadcasting	Manual broadcaster		Seem cum ferti drill, Top dresser, Spreader,
4.	Irrigation	Dhikki pump, Roar pump		Lift irrigation, Shallow or Deep tube well, Drip or Sprinkler irrigation, Surface and Submersible pumps, Solar irrigation pumps, Diesel or gasoline pumps, Axial flow pumps
5.	Weeding/intercultivation and earthing up	Manual weeder, Kuto, Paate khurpis, Spade, Hand hoe	Traditional or improved plough,	Power weeder, Cultivator, Mini tiller weeder, 4WT weeders, Ridge maker, Rotary weeder
6.	Plant protection	Small hand sprayer, Compression sprayer, Foot or pedal sprayer, Knapsack sprayer		Solar or electricity charged backpack sprayer, Power sprayer, Electric sprayer, Boom sprayer, Monkey repeller
7.	Harvesting	Kodalo, Kuto, Traditional or improved sickle, Sikechar, Saw, Manual harvesters		Mini/2WT/4WT Reaper, Self-propelled reaper, Brush cutter, Mower, Large or mini combine harvester, Potato digger, Maize dehusker cum sheller
8.	Threshing, cleaning and grading	Stick, Nanglow, Manual sheller	Animal tramping, Bullock treading	Power thresher, Seed cleaner, Grader, Seed cleaner cum grader, Multi-crop thresher, Pulper
9.	Hey management			Straw reaper, Baler, Fodder harvester, Mulcher, Chaff cutter
10.	Transporting	Doko, Crate, Hand trolley	Animal drawn rickshaw, Bullock cart, Donkeys	Power tiller and tractor trailers, Ropeway, Four-wheel vehicle or pick up
11.	Drying and storage	Open sun drying		Different mobile and stationary Dryers, Tunnel dryer, Storage structures
12.	Agro Processing	Dhikki, Jantos, Okhal, Manual seed extractor	Traditional kol	Water mill, Huller, Sheller, Oil extraction mills, Disc/hammer Mills, Combine mill

4.1 Land preparation

a. Tillage

Tillage is basically defined as mechanical manipulation of soil that is performed to attain the desired seedbed for providing an optimum environment for seed germination and plant growth. Tillage consists of primary and secondary tillage operations. Under primary tillage, cutting and turning of furrow slice is carried out to pulverize the soil and bury weeds and weed seeds inside the soil layers. The tenacity of soil preparation works (secondary tillage) accomplished after the ploughing consist of breaking and crushing the larger structural soil clods along with levelling of field in order to sow. In spite of power intensive operation, tillage in hilly rural areas, is mostly done through manual labour using local hand tools (spade, hoes, spades, shovels, fork hoe) or through animal draft power (animal drawn local wooden plough) etc. The use of engine-powered bigger and heavy machines such as large tractors for land preparation especially hilly areas is not feasible because of the rugged and

narrow terrain, and lack of access roads in remote production areas. But, these days, increasing use of imported low (5-9) HP small mini tiller contributed in mechanized ploughing in the hilly areas.

In the context of terai, almost all the tillage operation has been mechanized by tractors compared to other operations. In terai belt, different kinds of manual tools, animal drawn implements (ploughs, harrows, and cultivators) and mechanical power operated tillage implements are used for land preparation activities. These days, the popularity for four-wheel tractors and power tiller along with their attachments for land preparation is high in terai or flat regions and low land of hills mostly through custom hiring method. Mostly tractor attached MB plough or disc plough is used for primary tillage works while tyne type cultivator, harrows, rotavator etc. are used for secondary tillage work. The choice of types of machines or tractors depends on the various meters like machine and land size, land condition, humidity, energy consumption of agricultural machinery and maneuverability (Copcea et al., 2022).



Figure 1: Land preparation: Animal drawn harrow (A), Four-wheel tractor (B), Small tiller (C)

4.2 Crop establishment

a. Seeding or sowing cultivation

In hilly regions, manual method is common for seed sowing despite low efficiency and back ache for the farmers. Broadcasting, behind plough (seed being dribbled in the furrow made by the animal drawn plough), line sowing, dibbling and drilling are the majorly implemented techniques of maize sowing in Nepal. The broadcasting technique is time consuming and also difficult to do inter-cultural operation such as weeding, earthing up, fertilizer use and harvesting. Regarding line sowing, it is easier to carry out those inter-cultural operations by the use of machine. These days, different types of manual planter are also available in country to sow seed.

Although, the use of tractors drawn planters like pneumatic planter, bed and furrow planter are already in existence in globe, their application in Nepal just started few years ago in limited adaptive research basis. Currently in terai belt, different models of four-wheel tractor operated maize/multi crop planter are being attempted slowly to be used which can plant seed and apply chemical fertilizer simultaneously. For the past few years, various imported maize sowing machines attached to four-wheeled tractors are being tested and researched for sowing maize seed. For instance, Agricultural Implements Research Station, Ranighat, Birgunj, under NARC is expanding four-wheel tractor operated three row precision maize planting machine in the pocket area after finding it beneficial for the farmers through on station and farmer's field research (Figure 2C). The slow spreading of these crop establishment technologies is due to the lack of proper extension services to demonstrate and convince the farmers and service providers of these crop establishment equipment. In addition, despite the positive moves, this method of planting is above the reach of the financial capacity of the individual farmers. Thus cooperative farming and investment or custom hiring model need to be adopted for the use of those expensive machines.

Likewise, mini tiller attached multi crop seed drill suitable for mid hills areas is currently under research phase which yet need detail investigation before recommending to farmers. In terms of hilly areas, there has been no any successful test and implementation of farmer friendly tractor operated sowing machine till now. Freshly, resource conservation technologies (RCTs) namely, minimum tillage, surface seeding, zero tillage, jab seeder etc. also being attempted to apply in several maize based cropping systems. Following are some of the machines that started to use in Nepal:

- **Jab seeder/planter:** For maize planting in hills and mountains, germination is found to be poor due to loss of residual soil moisture by tillage operation. Soil erosion takes place in rainy season and conservation practices are lacking. In this context, different kinds of jab

seeder are used for dibbling maize. For example, NAERC jab seeder can be used for simultaneous sowing maize and fertilizing with conservation tillage option for the hilly and mountain areas of Nepal. It is lightweight (5 kg) and can seed more than 0.05 ha of land in an hour and has following advantages: It can be used in untilled land; residual moisture is conserved; offers better germination; and ensures increased fertilizer use efficiency. It is women friendly equipment as dibbling operation is carried out in standing posture and discomfort due to the bending is avoided. Besides this, different kinds of imported manual dibbler are also available in Nepalese market suitable for sowing maize in small plots or hilly terrains.

- **Rotary dibbler:** It is a manual push type planter for sowing seeds such as maize, soybean etc. along with drilling of chemical fertilizer. It consists of a rotating dibbling head with penetrating jaws, seed hopper with cell type roller, covering cum transport wheel seed and fertilizer box and a handle. During the operation, the hopper and box is filled with seeds and fertilizer, after then the dibbler is pushed forward in the direction of travel with transport wheel behind the dibbling head. This action will penetrate the jaws into the soil and drop the seeds inside the soil. The plant to plant distance depends upon size and number of the polygon plate to which jaws are attached.
- **Push row planter:** This is a cycle type push planter which is suitable for multi crops seeding and fertilizing, such as corn, wheat, vegetable seeds and other similar sizes of cereals. This planter can apply fertilizer, sow seeds into the soil, and also cover the soil. The depth of sowing, row spacing, and number of seed drop can be adjustable.
- **Multi crop mini tiller seed drill:** This kind of mini tiller attached seed drill can be used for sowing maize, wheat, etc. especially in hilly regions where mini tiller is currently expanding as tillage implements. The inclusion of seed drill in maize cultivation can diversify the use and enhance the working hour of mini tiller.
- **Zero till seed drills for maize seeding:** Under this method, planting is done in stubble of previous crop without any soil disturbance/tillage operation. Manual jab seeder can be used for small scale farming whereas tractor attached seed drill for big scale. The integration of residue mulching with this planting method can protect the crop during adverse conditions by preserving the moisture of soil.
- **Precision maize planter:** This is a four-wheel tractor mounted planter which can sow the seeds, disperse fertilizer, cover and press inside the soil in one operation. This planter is mostly suitable for terai region. Seeding assembly can adjust the sowing depth according to land topographic inequality along with stable sowing depth and proper maize seeding.

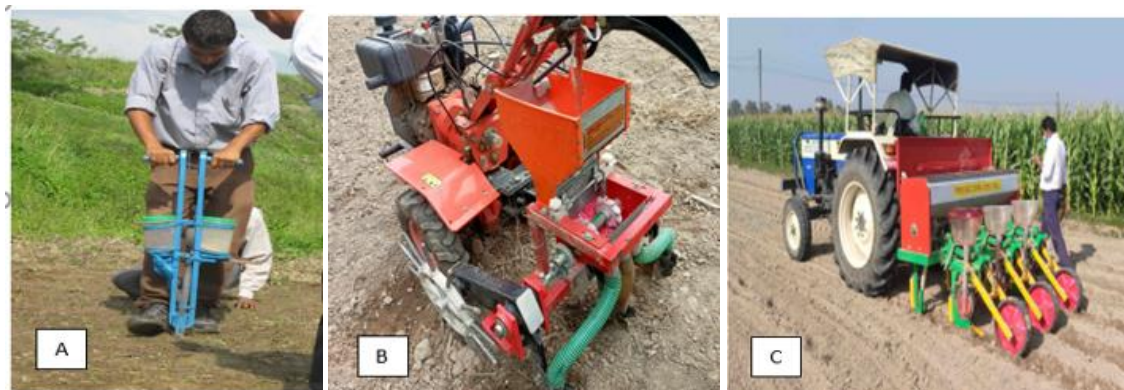


Figure 2: Jab Seeder developed by authors (A), Min tiller seed drill (B), AIRS promoted 4-wheel tractor drawn precision maize planter (C, Photo Source: The Kathmandu Post, 2023)

b) Fertilizer application

Mostly manual method is common in fertilizer application throughout land preparation followed by top dressing. Regarding compost manure, generally women dug it, loaded in bamboo baskets and carried out on their backs to the fields. After then it is spread out manually before ploughing. Similarly, chemical fertilizer is applied through broadcast method while some using fertilizer broadcaster (for paddy). In case of row crops like maize, fertilizer is applied with manual pouring method. Different kinds of manure spreader operated with tractors that are used in abroad need to have adaptive research based on nation condition before promoting in Nepal.

c) Weeding and interculture

In Nepal, weeding is one of the most tedious and time consuming work which is mostly done by female manually using small hand tools. In Karnali and Lumbini province, such as Rukum and Rolpa district, animal (oxen) drawn plough is still in use for maize weeding purposes. Presently, different kinds of row crop manual weeders and sweep cultivators are being started to be used for interculture operation on limited scale. For instance, NAERC and AIRC developed manual weeders can be used by female for weeding purposes in row crop. Efforts are being made to promote imported walk behind type multi row power weeding machines as well as attachments to small tractors for hilly belt. Following are some of the manual and power assisted weeder:

- Manual weeding tools

- Small traditional tools such as hand hoes (*kutto* in Nepali): This small tool is hand held type hoe like '*kutto*' which is operated in squatting posture of the operator and has very low work rate. This is suitable for eliminating weeds in between rows and fields with broadcasted or line sowing seeds.
- Long or short handle spades or chopping hoes (*kodalo, kodali* in Nepali): It works on principal of impact and has straight, curved or pronged sharp blades that cut a slice of top soil along with the weeds. This is operated in bending posture of operator and the weeding work is slow and tiresome.
- Manual wheel hoe: This kind of manual weeder works on principal of push-pull stroke of operator and are generally provided with one or two wheels. This is generally suitable for row crop weeding and operated in standing posture of the operator. The weeder consist of soil working tool having one or more blades that can uproot and cut the weeds.

- Mechanical weeder and tractor drawn cultivator (sweep cultivator)

Self-propelled power weeder powered by 3-9 HP diesel or petrol engine can be used for weeding in row crops having row spacing more than 45cm. Currently, the use of power weeder in Nepal seems very limited and most

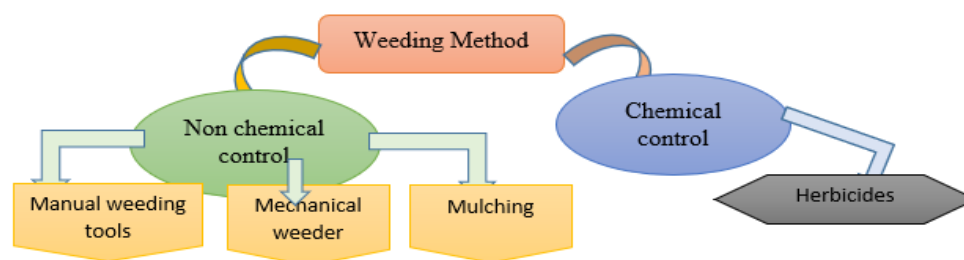


Figure 3: Schematic diagram of manual and mechanized weeding trend in Nepal

d) Plant protection/spraying:

Spraying and dusting is an imperative plant protection operation during the crop production. Farmers mostly used small hand sprayer and Knapsack (battery operated or manually operated) sprayer for spraying insecticides, pesticides and fungicides on small trees, shrubs and row crops for the control of insects, pests and diseases. Briefly, the operating principle of manual knapsack sprayer includes: The pump handle extending over or under the operator's shoulder shall be operated by short up and down strokes to pump and spray. Maintaining a constant pressure can be ensured by maintaining the pump in full operation. The spray liquid is forced out of the spraying nozzle when opening the control valve, by maintaining a steady pressure so that the pump remains in continuous operation. These days, small portable power sprayer (engine or electric motor operated) are also available for spraying purposes. Boom sprayer is another plant protection equipment which can spray larger area with short time. This sprayer is appropriate for wide space row crops having enough row to row spacing for movement of tractor. These sprayers are suitable for pre-emergence and early post emergence application of agro-chemicals as the clearance provided in the boom sprayer mounting frame was not sufficient for crop more than 45 cm height. There is no doubt that use of mechanical sprayers warrants timely plant protection and efficient usage of agro-chemicals. But the major point to be considered is crop plantation need to be done in rows keeping in view the mobility of tractor. Although, researchers are accompanying experimental studies on the adaptability of imported mechanical sprayer in Nepal. For instance, AIRC, NARC is endeavoring to do adaptive research of tractor operated boom sprayer for terai belt of Nepal. Still, we are lacking in the studies of design, development and testing of precision spraying technologies (developed in our own nation) for crops and orchards. Different kinds of high efficiency sprayers such as Ultra-low volume (ULV) sprayer, aero blast tractor sprayers, power operated mist blower and dust sprayers, and electrostatic sprayers, plant protection drone or unmanned aerial vehicles (UAV) aircraft (aerial spraying) for precision agriculture (Bamboriya et al., 2020; Dela-Cruz et al., 2017) are being researched and practiced in the other countries that are rarely researched in Nepal (Khatri and Shrestha, 2022).

- Repelling technologies for bird and monkey management

The yield loss and crop damage by animals and bird feeding is increasing day by day from crop field. The emerging problem of farmer in field is to

of them are used through different stakeholders in research and demonstration concept. Basically, this kind of power weeder consists of discs mounted with curved blades. The rotating blades cuts weeds and integrate into the soil. Similarly, Brush cutter can be used as weeding tools in row crops by attaching weeding blades component in head of cutter. Likewise, regarding flat belts of Nepal, tractor drawn multi row tyne or sweep type cultivator and PTO driven multi-row rotary weeder can be a mechanization tools for weeding purposes. But, tractor mounted weeding implements can be used only during the early stages of crop because limited tractor and cultivator ground clearance damage the crop foliage at later growth stages. It is also necessary to have shallow working depth to prevent plant roots damage.

Similarly, the use of pre- and post-emergence weedicides or herbicides is also getting popular in Nepal due to tedious weeding work and lack of agricultural labour. Sometimes, it is also difficult to enter in the field for weeding due to continuous rains during the early crop stages. Thus, the only effective way to control weeds in this circumstances is the use of herbicides. However, it is recommended to have mechanical and chemical methods for weed control as a complete interconnected plant protection system. In the same way, mulching method can be followed by keeping crop residues or plastic sheets on the soil surface within the crop rows especially for winter maize. Mulching aids in moisture preservation, temperature regulation and weed control in field crops.

save seed/crop from different birds and animals especially monkeys. Still the traditional way of repelling such as placement of shinning tape or reflective ribbon throughout the field, use of scarecrow (*Bukhyacha*) for bird; and chasing, shouting, guarding with farm dogs, beating with sticks and throwing stones for animals are in practice to minimize crop damage from them. Electronic birds repelling devices producing different recorded natural sound of bird predators and alarm call of pest birds in certain interval are being practiced in foreign countries in crop field. Considering those, NAERC has attempted to develop metallic framed bird repeller (looks like human structure) which can produce different sound as well as metallic arm that can swing in certain interval to scare bird. This is still in research phase and yet to be commercialized. Likewise, NAERC had develop metallic monkey repeller to address the acute problems of monkey menace in the mid hills of Nepal. This kind of auditory deterrent (air cannons that produce large blasting sound by the use of calcium carbide and water) can be used as repelling tools for bird too. After the increasing demand of the repeller from farmers of various districts, handover of this technology is made to two local manufacturers (Chandragiri Machinery Udhog Pvt. Ltd., Kathmandu and J.B. Workshop, Lalitpur) for its commercial production.



Figure 4: Monkey Repeller (developed by authors)

e) Irrigation Water management

Although, maize in Nepal is mostly a rain-fed crop, in some ecologies (terai belt), it requires frequent irrigation for winter maize to grow. Increment of irrigation scheme for winter maize belt can open up new avenue for maize cultivation which can increase the overall maize production and productivity in the country. Irrigation is mostly done by flooding or furrow irrigation method where ample water is available. In areas where canal

irrigation is not accessible and where underground water is ample, turbine and submersible pumps for deep wells, and centrifugal pumps for shallow tube well are used for irrigation. These days, to some an extent, sprinkle irrigation, drip irrigation and solar pumping irrigation are also being started to be used due to government subsidy on these systems. Different types of electricity/diesel operated water lifting pumps which includes axial flow, mixed flow pumps, mini tiller or power tiller attached pump etc. are also accessible in market for lifting irrigation water.



Figure 5: Mini tiller water pump (A), Sprinkler irrigation (B)

4.3 Harvesting

Harvesting is considered as one of the key and critical field operations of maize production to attain better quality and greater yield particularly under bad weather circumstances. In Nepal, the traditional practice of maize harvesting consists of manual picking of mature cobs followed by stubble cutting with sickles. This method is labour and time intensive practices as well as comprises lot of drudgery. Mechanized harvesting is recognized as the most promising area of intervention in maize harvesting from field to tackle increasing phenomena of labour scarcity and costs and to fuel farm prosperity and entrepreneurial opportunity in the rural part of the country (Khatri and Shrestha, 2022). According to the harvesting approaches, maize harvesters could be categorized into two types, one is maize-for-grain harvesters, including pickers and grain harvesters, the other is whole plant harvesters, including fodder harvesters and combined grain stover harvesters. Around the world, mechanical harvesters like self-propelled combine harvester, hand held self-propelled harvester, forage harvester-cum-chopper, have been investigated and practiced improving profitability and efficiency of maize farming (Jaidka et al., 2020; Gurung et al., 2017; Dela-cruz et al., 2017; Bamboriya et al., 2020). However, there are major issues such as the crop cultivation method and pattern, flexibility, high cost of machines, small and fragmented holdings, and sloping land that limits the investment capability and also slowed the spread of the mechanical harvesters in Nepal. Moreover, the application of

combine harvester or reaper still seems in research or demonstration stage for mechanized harvesting in the country. For instance, AIRS-Ranighat and DOAR-Tarahara is currently prioritizing research of imported combine harvester for maize harvesting in terai belt. In the Terai, all the stakeholder need to focus on above mentioned mechanized maize harvesting bottlenecks. Regarding hills of Nepal, there is no any research verified technologies on mechanized maize harvesting till yet.

4.4 Chaff cutting (Chaff cutter)

The harvested green or dry fodder as well as maize stalk need to be cut into small pieces either for efficient animal feeding or for composting purposes. Mostly, women have to perform this work in villages. Traditional type of manual chaff cutters as well as sharp sickles are used by farmers for cutting since a long time. But these days, different kinds of manual, electric and tractor mounted movable chaff cutter are also available in Nepal and can be used by small dairy farm, medium dairy farm and large dairy farm, respectively. For instance, large flywheel type chaff cutter is a commonly used machine in the Terai region. Likewise, electric small chaff cutter is getting popular in the hills as well in Terai. However, due to lack of safety and operational training, there have been increasing incidences of farms accidents and injuries involving women and children caused by haphazard use of unsafe fodder chopping machines.



Figure 6: Chaff Cutter (A-fly wheel type and B-drum type)

4.5 Shelling

In the past, most of the farmers applied traditional method for shelling of cob such as use of human finger to remove kernels, manual rubbing maize cobs against one another, beating the de-husked cobs with sickle, wooden plank or sticks and treading with animal that need more manpower in terms of energy and time. Presently, the scenario has changed and most of the farmers use manual hand tools (tubular maize sheller and hand cranked rotary sheller) and powered operated sheller machines (electric corn sheller-single tube or double tube, dehusker, tractor (PTO) driven threshers etc.). Since mid-nineties NAERC, NARC conducting research and promotional activities of the tubular corn sheller for the small farmers in

the hills (Shrestha et al., 2003). These days, small electric type corn sheller is getting popular in the hills. Briefly, following are the shellers used in Nepal:

- a) Manual corn shellers: These kind of sheller are available in tubular or rotary type. It is hand operated sheller suitable for separating of maize grains from individual dry and dehusked cobs. It is tubular in shape and possess four tapered fins to remove maize grain from dehusked cobs. The capacity of the NAERC sheller is about 13-15 kg/h as against 10-12 kg/h in traditional method. Similarly, manually operated rotary maize shellers are suitable for small to medium farmers.

- b) Pedal operated maize sheller: The hand shelling of maize is laborious and time consuming. This sheller works without electrical power source and does not need extra skills (Shrestha et al., 2003). It is cheaper and easily affordable by small farmers.
- c) Electric corn Sheller: This kind of sheller can have single tube or multi tube feeding inlet. The power source is single phase electric motor. De-huskers are used to separate the husks that cover maize cobs, while shellers separate the grain from the cob. In this sheller, maize needed to be dehusked first manually or with dehusker before shelling.
- d) Maize dehusker cum sheller: This kind of de-huskers cum shellers are machines that first de-husks the maize cob and then shells the grain from the cobs simultaneously. Likewise, electric powered

Chinese machines (1-3 HP) having either de-huskers/shellers or combination of both function are also available in smaller sizes which can dehusk and shell the maize separately or both.

- e) Tractor operated maize sheller: This kind of thresher is mobile and tractor (PTO) driven threshers that is trailed behind a 4WT and is most popular in the Terai region. Usually, service providers travel from village to village for providing the threshing service. Even, small engine powered shellers are transported on four-wheel tractor trailers or pick up during the threshing season from door to door. In terai region, maize shellers having function of both dehusking and shelling grains operated by tractor PTO Shaft are popular nowadays. Similarly, multi-crop threshers can shell maize cobs but dehusking was a prerequisite step.

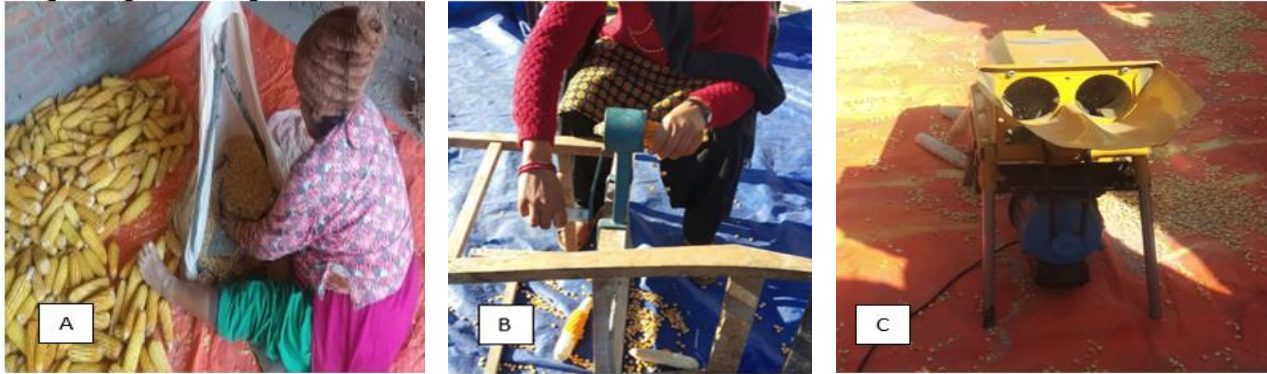


Figure 7: Manual shelling (beating with sickle) (A), Manual maize sheller (B), Electric maize sheller (C)

4.6 Post-harvest practices

Post-harvest handling encompasses the management of agricultural produce before processing which involves drying, cleaning, grading and storage. Nepalese farmers are applying unique traditional practices of post-harvest storage of maize in which external cob storage was the common method. Farmers hung the maize cobs along the roof or varandha of the house by making small bunches (*Jhutta* in nepali) to expose it to air. In a similarly way, farmers typically stored with sheath intact on local wooden or bamboo structure made on a vertical pole with a crop straw roof covering (*Thangro*). Such types of traditional storage methods are habitually exposed to the menace of maize weevils, fungi and rodents. Similarly, in rural village, farmers use firewood for cooking purposes, so they also hang maize bunches for drying in kitchen ceiling using long bamboo. The smoking method helps to reduce insect infestation and moisture content and the chemicals in smoke dissuades insect from laying eggs. In other side, different modern methods including storage in sacks, metal silos or bins, chemical treatment for seed, and hermetically sealed bags (i.e., Purdue Improved Crop Storage- PICS bags, and Super Grain bags etc.) are also promoted by different stakeholders to maintain quality of stored seeds and grains, and reduce post-harvest losses in storage condition (Kandel et al., 2021; Devkota et al., 2018). However, the application of these technologies among farmers remains low due to limited awareness and unavailability. Regarding drying, sun drying is common in Nepal. Recently, imported mechanical seed dryer or tower dryer for drying maize, wheat and paddy is introduced in Nepal through different stakeholders in limited number through subsidized mechanism. NARC also procured multi grain dryers for its different stations to conduct adaptability research based on technical and economic viability aspect to

farmers. This kind of expensive dryer which require big investment need to be promoted only after detail analysis of financial benefit to the users. In the case of grain winnowing, it is mostly manual using bamboo 'nanglos' and electric fan. NAERC manual seed cleaner can be used for multi grains including maize after threshing or shelling. Likewise, electric motor driven cleaner is currently being under research which need detailed testing and verification before dissemination to farmers.

4.7 Processing and packaging

Most of the rural villages of Nepal were dependent on traditional milling and grinding practices such as traditional water mill (Paani Ghatta), quern, mortar and pestle (Jhantos, Okhal and Dhikis) which are very slow, labour-intensive, tedious, drudgerious and low output practices. Presently, with the advancement of technologies, different types of modern automated milling machines such as sheller, huller, disk mill, and polisher are being used in the country. Increasing trend of machine milling and grinding has gradually replacing the traditional method of processing. Most of the bigger mills are established in terai regions although the investment cost is also very high. These kind of bigger capacity mills are not appropriate in hills and mountains due to geographical and economic constraints. Considering this aspect, presently, small post-harvest processing enterprises comprising rice milling, flour milling, oil milling and cereal flaking are also increasing in rural Nepal for providing custom service. Mini combine mill cum grind machine having function of two in one (milling and grinding) is also emerging as one of the affordable postharvest mechanization option in the rural areas of mountainous and hilly regions (Khatri, 2020).



Figure 8: Small scale grain processing center in rural area (A) and Combine mill (B)

5. KEY FACTORS (DYNAMICS) ON HINDERING THE ADOPTION OF AGRICULTURAL MACHINERY

- Geographical constraints: Small scale of farmland, physical restraints of steep and rugged terrain and constricted terraced farming in hills and mountains is a key barrier limiting the use of machines which resulted slow pace adoption of agricultural mechanization in hills.
- Limited gender friendly machines: Role of women is increasing day by day due to increasing out flux of male members of household to urban area and abroad in search of job. Most machines are not gender friendly (particularly for women). For instance, body vibration during operation of mini tiller is currently discouraging the women to operate by them in hills.
- Difficult access to credit and insurance systems in remote areas: Subsistence or small-scale farmers have limited purchasing power and often purchasing agricultural inputs (seed, fertilizer etc.) become a noteworthy investment for them. Considering this, the government implemented the credit facilities and insurance schemes through banks and insurance company. For example, the government has started providing agriculture insurance facilities (75-80% subsidy in insurance fee for the agricultural insurance through different insurance company like Rastriya Beema Company Ltd., Shikhar insurance etc.) to the farmers since FY 2070/71 aiming to discourage imports and make the country self-reliant in agriculture. However, it is not yet getting momentum as expected and still beyond the reach of rural poor farmers. The disinterest of farmers towards crop insurance could be the short crop period (less than three months). According to the Agriculture and Livestock Directive 2077, subsidized insurance policies require to be registered for a year and less than this period will not get subsidy aids (Beema Samiti, 2021). Other reason could be tedious procedure and even detail documents and compliances required for small volume loan, lack of adequate awareness on crop insurance and agricultural credit to the illiterate farmers, and subsistence nature of farming. Narrow access to credits and high credit interest rates for tractors and other agriculture machineries increases farmer's unwillingness in machinery purchase.
- Technological constraints: High purchasing cost of machines and price discrepancy of same machine (for example, mini tiller) was a barrier that is creating confusion among farmers on model selection and quality product. Difficulty in timely availability of spare parts, high cost of spare parts, lack of training on operation and maintenance of farm machinery and inadequate repair and service facilities of machinery in remote areas are considered as key hindrance for machinery adoption.
- Farming and environmental challenges: Unpredictable climatic changes, vulnerable weather pattern and decreasing water resources are the environmental challenges. While, timely availability and costs of inputs like seed and fertilizer are the prime concern of farmers which limits their mechanization concern.
- Custom hiring service providers and subsidy issues: Although subsidies can escalate farmer's enthusiasm for purchasing machines, the current scheme of subsidies for machine purchase has some limits comprising narrow boundary, poor product quality, poor awareness of after-sales service, supply rather than demand-driven introduction of machines and political influence or biasness on machine distribution. Government is also attempting to enhance the custom hiring service through its different subsidy program. As most of the custom hiring service are operating in informal basis, the farmers are compelled to pay irrational charges and did not find any authority to complain about the hiring cost and service quality. Also, there is lacking of proper field level monitoring and evaluation on use of subsidized machineries.
- Poor mechanization research, education and extension services (institutional constraints): Many farmers, especially in remote areas have not seen or even heard about new machinery technologies that could enhance their farming operations. Institutions for research, extension and educational program are very weak and have less prioritized mechanization work. Mechanization research organizations such as NARC (NAERC-Khumaltar, AIRS- Ranighat, NMRP-Chitwan etc.) and its other wings lack adequate resources, agricultural engineering related technical manpower and infrastructure facilities which bounded them to do work in limited basis. Despite the well mentioned mandate of each stakeholder, coordination among research, education and extension seems very poor in Nepalese context which might be due to distrust environment and credit taking rivalry among the

stakeholders. Most of the agricultural extensions and educational institutions have no mechanization disciplines and manpower.

- Quality, accidental and safety issues of agricultural machines: The arbitrary dispersal of agriculture machinery and tools without proper study on topography suitability, machinery performance and safety features as well as effective training to the operator or end user enormously increasing accident and injuries. AMTRC-Nawalpur is currently performing individual and confidential testing of few machines in a limited basis following the foreign guidelines and unable to conduct testing and monitoring (quality and safety) of all 100% imported machines due to limited technical manpower, absence of own testing protocols and guidelines matching with agro ecology, inadequate funds and infrastructure facilities.
- Local fabrication of agricultural machinery and tools: Traditional artisans (blacksmiths) are struggling to survive and at the verge of extinction due to obsolete and traditional workshop facilities, costly raw materials and absence of technical and capital support to advance their professional skill and service. Similarly, imported tools and machines (cheaper than their cost) diminishes the demand of tools developed by them. Small and medium sized fabrication enterprises and workshop have partial financial and technical backstopping to fabricate sophisticated agricultural machines and equipment. The encouraging step is government has made VAT free for the locally produced agricultural tools and equipment to the farmers. However, that are still issues of the VAT reimbursement for raw materials which manufacturers have to pay. Thus, government need to facilitate entrepreneurs through favorable policy related to raw materials for machinery fabrication along with strict monitoring.
- Increasing fallow land or Arable land abandonment and land fragmentation: According to Nepal's Ministry of Land management, Cooperatives and Poverty Alleviation, 5.49 million hectares of land are cultivated while 1.03 million hectares left fallow throughout Nepal in 2018 (Dahal, 2020). Due to rapid outmigration in rural areas and increased wild animal menace (crop damage by wild animals mainly monkey and wild boar in the mid hills), human wild life conflict and fallow land is soaring up every year. Even the cultivate crop is hard to protect from monkey which compelled farmers to leave land as fallow in the mid hills areas of Nepal which is still considered as major pocket of maize production. Land fragmentation is high in rapidly urbanizing Terai and low land valleys whereas increasing fallow land and landlord absenteeism is extensively predominant in hilly areas; both of these scenarios has fetched alterations in land use pattern for agricultural crops.
- Miscellaneous challenges: This includes poor infrastructure (agricultural road, irrigation facilities) in rural areas which increase cost associated with machinery and services, and produce transportation cost. Also, imported machinery and tools are being attempted to use in country erratic topography without study on suitability to local condition. In the name of mechanization, haphazard distribution of machines based on supply rather than demand driven is also leading to the technology negativity or mechanization failure.

6. RECOMMENDED FUTURE DRIVING PATHWAYS

Table 4 represent the probable research zones and recommended solutions for whole process mechanization in maize. Additionally, in the strategy for uplifting mechanized agriculture, the following paths are stipulated:

- Public private partnership (PPP model): There is need of synchronized associations and efforts among public and private institutions to research, design and develop need based engineering technologies for different types of farmers and farming structures. The spread of agricultural mechanization can be boosted by enabling all actors in the entire mechanization value chain through well-united mechanization support scheme based on PPP model.
- Development and promotion of small scale machinery: As the average landholding per family is less than 0.68 ha, most maize produced in Nepal comes from small scale rural farmers who depend mostly on human or animal power. To address the constraint of small farm holdings, small machines such as manual planter, weeder, manual or electric sheller, combine mill etc. should be developed or promoted for individual or small farming communities. Even if small hand tractors are used in the market area, there is still a belief that plowing should be done by oxen in the village of remote areas. Thus, development and promotion of animal drawn tools such as improved metallic plough,

planter and cultivator could help to enhance their farming activities. The government need to plan and prioritize to give subsidies for encouraging the farmers who keep livestock. In other words, the elementary prerequisite for the effective extension of farm mechanization are simple design and technology, flexibility for usage in different farm operations, suitability to small farms, cost affordability and the endowment of support services.

- Development and promotional work of resilient maize varieties: To combat the changing vulnerable climate change, NARC released and verified resilient maize varieties for combating cold stress and heat stress for terai region and drought tolerant for hills region need to be prioritized for promotional work. NARC also need to give more priority in varietal development and multiplication to address the issues of climate change.
- Assurance of irrigation facilities: In Terai belt where winter maize is planted, irrigation is prime requirement for enhancing the maize cultivation. Thus, there is extremely necessary to have proper and well equipped irrigation amenities that include surface or canal irrigation, irrigation pumps, shallow or deep tube wells.
- Research priority on planting and harvesting technologies: It is required to have detail adaptive and institutional investigative studies on four-wheel tractor operated maize planter, self-propelled reaper and combine harvester for flat land while small harvesting tools in hilly region on the basis of technical, financial and social aspects. Later on the basis of verified research and size of farm scale, the maize planter and harvester (combine harvester, and crawler-type harvesters, medium and small size harvesters and hand tools) that are suitable for the local geographic and economic conditions should be promoted in different areas. Government also need to prioritize and support the local R&D entrepreneurs through its research wing to research and develop the suitable planter or harvester.
- Inclusion and promotion of gender friendly and sustainable conservation agriculture technologies: It is also necessary to promote women friendly and sustainable technologies such as conservation agriculture and scale-appropriate small machines like corn shellers, jab seeder, small weeder, monkey repeller etc.
- Enhancing the power of private or local manufacturers/blacksmiths: It is necessary to uplift local manufacturing sectors for developing machines, hand tools and spare parts to reduce trade deficit and the tariff for spare parts. It is important to revise regulation and tax/VAT on raw materials favorable to local manufacturers to build agricultural machinery suitable for smallholder farming. It is also possible to waive the VAT and import duty on spare parts to reduce the machine maintenance cost and discourage the illegal import of low quality spare parts through the nearby border. It is also suggested to provide financial incentives to traditional artisan in improving their workshop facilities because most of the agricultural hand tools still fulfilled by those communities in rural areas. Finally, a well-designed mechanization approach is needed to backstopping local-level inventions and their adaptation into technologies in alliance with research organization.
- Strengthening agricultural engineering sector: Agricultural engineering has a significant role in the advancement of new agricultural technologies and engineering-based methodologies for the management and protection of crop, soil, water, and environmental resources. Considering this aspect, the governmental research institutes have to prioritize digital agriculture research or farming solutions based on new tools such as artificial intelligence, block chain, remote sensing, GIS, drones and robots etc. in the area of agricultural mechanization, automation and robotics, UAV plant protection machines, high-efficiency irrigation systems, farm energy systems, post-harvest handling and processing. Additionally, researchers need to invent or explore new technologies that could help the farmers to accurately find the climate forecast and water usage, for coping the erratic climatic changes. Regarding manpower, government need to immediately allocate at least one agricultural engineer in every research stations of NARC and also in each provincial and local level offices. Similarly, the syllabus and capability of agricultural engineering program at Purbanchal campus, Tribhuvan University, Dharan is desirable to be refreshed based on current advancement in mechanized technologies around world along with compulsory practicum in professional organizations to acquire more practical skills for sustainability in competitive professional market.
- Information and communication technology (ICT) tools: In this modern era, ICT tools like cell phone, television, internet and computers might help to gain rapid momentum in Nepal's agriculture mechanization discourse as compared to traditional agriculture extension. But, low ICT literacy, high cost, poor and complicated access and farmer poverty are becoming the potential roadblocks to ICT adoption in agriculture. Thus, the acceptance and use of ICT tools and machines need awareness campaigns, training and through understanding to the user.
- Prioritize on multi-function or diversified use of machine: Considering interventions on maize mechanization, the multipurpose machine can have higher chance of being adopted by farmers as cropping systems are relatively diverse in Nepal. For instance, farmers prefer multi-purpose functionality tractors having implements for ploughing, ridging, water pumping, threshing, shelling and transportation which can increase annual working hour of machine.
- User protection through effective testing and price control regulation: It is immediately needed to strengthen the NAMTRC-Nawalpur (manpower and sufficient budget) to have proper functionality, own testing protocols, laws and regulations and well equipped testing facilities for all agricultural machines. NAMTRC need to focus instantly on testing and enforcement of protocol and standards, safety regulations, consumer information services, periodical publication of test reports, protection against unscrupulous commercial practices etc. There is very urgency of well functioned testing center to address the horse power (HP) variation issues of imported mini tillers to have consistency among them. After then, the Nepalese government should promote NAMTRC quality-tested and certified agricultural machines and need to strictly restrict import of low quality agricultural machines. In other part, the positive move was that Nepalese machinery supplier or dealer started to publish maximum retail price of their products in the national daily newspaper since few years. Still, Nepalese farmers are in dilemma about the price variation for the same machine (for example mini tiller), thus, government have to strictly control or monitor the price by formulating appropriate regulations or policies.
- Repair/maintenance facilities and training/dissemination program: In remote areas, there is a lack of repair and maintenance workshops facilities and technical manpower which compelled farmers to go to long distances nearby district headquarter or cities areas even for general servicing and repairing of machines. Thus, farmer's skill enhancement in the sector of safe operation, repair and maintenance of machines through conducting effective technical training courses or dissemination activities is urgent need of today. Similarly, middle level technician such as mechanic are prime requirement in each ward of municipality for providing service. For this CTEVT has to focus vocational training curriculum and program in the sector of agricultural mechanization.
- Improving technologies for post-harvest management: In Nepal, storage losses range from 5 to 30% for several cereal crops and are mostly caused by insects-pests, mold and rodents (Kandel et al., 2021; Devkota et al., 2018). Thus, it is necessary to reduce storage losses of maize by improving the farmer's storage systems and through the adoption of preventive measures as an integrated package. This can be achieved by promoting sustainable and improved modern storage methods such as storage in sacks, metal silos or bins, chemicals treatment for seed and hermetically sealed bags (Purdue Improved Crop Storage- PICS bags, and Super Grain bags etc.). Likewise, establishment of post-harvest center at each municipality as per local need basis to demonstrate and promote effective storage and processing technologies could have positive impact on maize post-harvest management sector.
- Effective Custom Hiring Centers: As most of the heavy machineries are expensive, it is not possible for individual small and marginal farmers to purchase all machines related to whole process mechanization. Government is attempting to support in purchase of equipment by individual farmers or for creation of Custom Hiring Centres (CHCs). The key intention of the subsidy scheme is to make machineries affordable by small farmer and to promote CHCs to provide machines and implements on nominal charge to the farmers. The machine rental service can lessen the labour scarcity problem and advance farm mechanization application in crop cultivation. Progressive farmers, rural jobless youth and agricultural engineering graduates has the opportunities of running custom hiring business. Even it is important that the CHCs need to be placed nearby the periphery of the small and marginal land holdings. Most important point to consider is that the

machines availability at various hiring centers would have to be decided upon the necessity of respective areas. Regarding sustainability of CHC, as most of the service facilitators are in their infancy, it is most important to have good record keeping such as machine use log book, income and expenses details for scientific and standardized rental business management. Provincial or local Government also need to motivate the CHCs by providing initial investment support and rewarding incentives during the operational period through proper monitoring to the CHCs that are providing effective services in nominal charges. Another alternative for custom hiring services could be set up of CHCs by the local governments in each rural municipality based on service demand. Importantly, national, provincial and local governments should come up jointly with clear policies, strategies and programs on mechanization to have more adaptability and agricultural productivity.

- Digitalization in use of custom hired machines: It is suggested to have brief information in digitalized form (internet, mobile app newspaper, TV, social media) about machine and service availability in hiring center. By referencing this, farmers can easily access the details of the rental machineries such as availability of the machine, associated rental cost etc. for whole process mechanization which will increase the use of machine properly in their farm.
- Strengthening the role of agricultural extension in the transfer and adoption of agricultural engineering technologies: Research institutes, public extension and other agencies have a significant role to effectively implement, demonstrate and promote suitable mechanization technologies. Farmers need suggestion and guidance in all aspect of agriculture like seed, fertilizers, pesticides, cultivation method, appropriate machinery and tools (make model, function, cost, service etc.) they have to purchase and use. Thus the extension stakeholders' role is to communicate the farmers on use of new technologies. The major approaches for promoting the developed and imported agricultural machinery includes coordinated effort from all stakeholders (research experimental stations, private commercial companies, university and extension department) for jointly providing machinery training courses, live demonstrations and practical operations on field days, and long-term intensive field orientation to farmers, machinery operators and service providers.

- Reclamation of abandoned or fallow land: Joint efforts from all stakeholders especially three tier of government is needed to cultivate or reclaim the fallow land of hills. Government need to support farmers for land consolidation to unify small scale/fragmented farmlands fields and mechanized farming, provide easy accessibility in institutional credit and crop insurance through subsidized interest rate, encourage returnee youth in commercial agriculture through targeted subsidy mechanism, organize effective machinery training, promote cooperative farming, improve infrastructure facilities (road, education, electricity, irrigation), fascinate farmers in crop insurance facilities through simplified process, apply well designed and sustainable mitigation strategies for human-wildlife conflict and improve marketing mechanisms for agricultural products. There is also a need of sustainable reverse migration scheme and incentives to deserving farmers irrespective of their political attachment to any political party.
- Revisit of policies and regulations: Agricultural Mechanization Policy 2071 (2014) need to be revised to streamline it according to new federal system of Nepal to effectively enhance or spread the machineries. The agricultural machinery related organizations are needed to be strengthened for the modernization of agriculture for the sustainable development of Nepal. In this context, there is a need to revisit our policy and program of three tier government for promotion of sustainable agricultural mechanization with transfer of appropriate technology addressing all the component of supply chain (not only mere distribution of machine).
- Easy availability of agricultural insurance and credit facilities: Considering the long term stability, it is conceivable to reduce or eliminate machine subsidies and incorporate these funds to reduce interest rates on loans and taxes for purchase of agricultural tools, equipment and machineries. Additionally, the procedure need to be simplified by categorizing small volume with basic compliances and large volume with detail documents and compliances for enhancing the loan and insurance facilities. To increase the uptake of agriculture insurance, it is necessary to conduct orientation and training programs for farmers, insurance agents and technicians.

Table 4: Recommended technological solutions for whole process maize mechanization in Nepal

Operations/ farming scale	Small Scale	Medium Scale	Large Scale
Tillage	Mini tiller, Power tiller, Animal drawn plough	Animal drawn plough, Power tiller or small tractor	Four wheel tractors with various types of ploughing attachments
Sowing	Animal driven planter*, Handheld jab seeder, Mini tiller seed drill*	Power tiller attached planter*	Precision row planter
Weeding	Manual weeder, Brush cutter with weeding tools, Small powered weeder	Brush cutter with weeding tools, Engine powered small weeder*	Tractor drawn cultivator
Spraying	Knapsack sprayer	Knapsack sprayer	High ground clearance sprayer (self-propelled or tractor attached type), Boom sprayer*, Plant protection drone*
Harvesting	Hand held harvesting equipment like brush cutter*	Small self-propelled harvester*	Row or Combine harvester*
Post-harvest	Hand sheller, Combine mill, Small electric sheller (single tube type)	Electric sheller (single or double tube), Maize dehusker cum sheller, Combine mill	Tractor drawn thresher or multi grain thresher, Maize dehusker cum sheller, Large scale mill

*Represent need of comprehensive research before promotion. Recommended technologies need to be adapted based on agro ecological topography suitability, farmer's need and custom hiring or community model basis.

REFERENCES

- ADS, 2015. Agriculture Development Strategy Government of Nepal. Ministry of Agriculture and Development. Kathmandu: Singha Durbar. http://www.doanepal.gov.np/downloadfile/ADS_FINAL_1542883806.pdf.
- AIRS, 2018. Annual Report, 2074/75 (2017/2018). Agriculture Implements Research Station, Nepal Agricultural Research Council, Ranighat, Parsa, Nepal.
- Beema Samiti. 2021. Agriculture-and-Livestock-Insurance Directive-2077-Ammendment-date-2077.11.17. Beema Samiti, Insurance

Regulatory Authority of Nepal. http://www.doanepal.gov.np/downloadfile/Agriculture-and-Livestock-Insurance%20Directive-2077-Ammendment-date-2077_1629440543.pdf

- Bamboriya, S.D., Jat, S.L., Shreelatha, D., Mahala, D.M., Rakshit, S. 2020. Mechanized maize production for enhanced productivity and profitability. IIMR Technical Bulletin 2020/1. Indian Institute of Maize Research, PAU Campus, Ludhiana-141004. <https://iimr.icar.gov.in/wp-content/uploads/2021/01/Mechanisation-in-Maize.pdf>
- Copcea, A.D., Mateoc-Sirb, N., Nița, L., Mateoc, T., Mihut, C., Stef, R., Scedei, D., Bungescu, S., 2022. Economic efficiency of mechanization technology of minimum works in maize. Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development, 22(1), Pp. 189-195.

- Dahal, K., 2020. Farmland in Nepal Lies Fallow as Youth Seek Opportunity Abroad. *Global Press Journal*. <https://globalpressjournal.com/asia/nepal/farmland-nepal-lies-fallow-youth-seek-opportunity-abroad/> (accessed 2022/09/10)
- Dela Cruz, R. S. M., Malanon, H. G., 2017. State of on-farm maize mechanization in the Philippines. *Agricultural Engineering International: CIGR Journal*, 19(4), Pp. 20–28.
- DOTM, 2022. Details of Registration of Transport up to Fiscal Year 2046/47-074/75 (1989/90- 2018/19). Department of Transport Management, Minbhawan, Kathmandu Nepal https://www.dotm.gov.np/Files/NoticePDF/Vehicledatattill20762020-01-17_04-54-21-965.pdf (accessed 2022/04/21)
- Devkota, M., Devkota, K.P., Acharya, S., Shrestha, R., McDonald, A.J., 2018. Establishing the value of modern seed storage methods for wheat in diverse production ecologies in Nepal. *Journal of Stored Products Research*, 76, Pp.71–76.
- Gurung, T.R., Kabir, W., Bokhtiar, S.M., (eds.). 2017. Mechanization for Sustainable Agricultural Intensification in SAARC Region. SAARC Agriculture Centre, Dhaka, Bangladesh, Pp.1-302.
- Jaidka, M., Bathla, S., Kaur, R., 2020. Improved Technologies for Higher Maize Production, In book: *Maize - Production and Use*. DOI: <http://dx.doi.org/10.5772/intechopen.88997>
- The Kathmandu Post, 2023. Modern equipment gives corn farming a much-needed boost. <https://kathmandupost.com/money/2023/04/29/modern-equipment-gives-corn-farming-a-much-needed-boost> (Accessed 2023/05/02)
- Kandel, P., Kharel, K., Njoroge, A., Smith, B.W., Díaz-Valderrama, J.R., Timilsina, R.H., Paudel, G.P., Baributsa, D., 2021. On-Farm Grain Storage and Challenges in Bagmati Province, Nepal. *Sustainability*, 13 (14): 7959, Pp.1-13. <https://doi.org/10.3390/su13147959>
- Kandel, S., Poudel, R., Saru, M. T., Parajuli, T., 2021. Status of farm mechanization and its impact on maize production in Jhapa District, Nepal. *Archives of Agriculture and Environmental Science*, 6(3), Pp. 290-294, <https://dx.doi.org/10.26832/24566632.2021.060304>
- KC, G., Karki, T.B., Shrestha, J., Achhami, B.B., 2015. Status and prospects of maize research in Nepal. *Journal of Maize Research and Development*, 1(1), Pp. 1-9. <http://dx.doi.org/10.3126/jmrd.v1i1.14239>
- Khatri, S., 2020. Performance Evaluation of Chinese Mini Combine Rice Mill cum Grind Machine. *International Journal of Engineering Research and General Science*, 8 (4), Pp. 22-34.
- Khatri, S., Shrestha, S., 2022. Mechanization in Fruit Cultivation: Present Status, Issues, Constraints and Future Aspects of Nepal. *Acta Mechanica Malaysia (AMM)*, Zibeline International Publishing, 5(2), Pp. 35-43.
- MoALD, 2022. Statistical information of Nepalese agriculture (2020/21). Government of Nepal, Ministry of Agricultural and Livestock Development, Planning & Development Cooperation Coordination Division, Statistics and Analysis Section, Singha Durbar, Kathmandu, Nepal.
- MoLESS, 2020. Nepal Labour Migration Report 2020. Ministry of Labour, Employment and Social Services, Singh Durbar, Kathmandu, Nepal.
- Paudyal, K.R., Ransom, J.K., Rajbhandari, N.P., Adhikari, K., Gerpacio, R.V., Pingali, P.L., 2001. *Maize in Nepal: Production Systems, Constraints, and Priorities for Research*. Kathmandu: NARC and CIMMYT, ISBN: 99933-205-0-1 <https://repository.cimmyt.org/bitstream/handle/10883/916/448434.pdf?sequence=1&isAllowed=y>
- Shrestha, K.B., Adhikary, S.K., Rasaily, R.G., Shrestha, G.L., 2004. Improved Tubular Corn Sheller: Appropriate Drudgery Reducing Agricultural Equipment for Maize Growers. *Agricultural Research for Enhancing Livelihood of Nepalese People*. In: Proceedings of 2nd SAS-N Convention, 30 July - 1 Aug 2003, Kathmandu BK Joshi, SL Joshi and KP Paudyal, eds. 2004, Pp.15-18.
- Shrestha, S., 2012. Status of agricultural mechanization in Nepal. In: Proceedings of Sustainable Agricultural Mechanization Roundtable: Moving Forward on the Sustainable Intensification of Agriculture 8-9 December 2011, Bangkok Thailand, United Nations Asian and Pacific Center for Agricultural Engineering and Machinery, Pp.1-4. <http://www.unapcaem.org/activities%20files/a1112rt/np.pdf>

