34 Agricultural Mechanization for Efficient Utilization of Input Resources to Improve Crop Production in Arid Region

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Abstract

Around 12% of India's geographical land is classified under arid soil where traditional rainfed farming predominates in most parts of these arid soils. It is very important to find or develop suitable techniques for agricultural mechanization in this area. In some areas of the country like Punjab and Haryana, mechanization has been increasingly fine-tuned and widely advocated by several farmers, thus enhancing the way of agricultural production with much ease and better efficiency. Agricultural mechanization plays an important role in increasing cropping intensity, precise sowing, and various crop input (seeds, chemicals, fertilizers, irrigation, water, etc.) utilization within a given time, to reduce the arduous labour of humans and animals along with permanent climate problems. Some suitable agricultural tools and techniques have been developed for the crops of this region to reduce the losses in crop production system which is very important to increase the overall productivity and production. This chapter focusses on the mechanized practices used in various farming activities from tillage to threshing and processing through efficient use of input resources for the arid region of Rajasthan. In today's era, robotics in agricultural work, Internet of Things in agricultural equipment, precision farming machinery, conservation techniques, renewable energy use in farm machines, and custom hiring centre should be given attention, so that the increase in demand for food can be met in the future and farmers can get more profit in crop production even in dry areas.

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Keywords

Agricultural mechanization · Productivity · Precision farming · Custom hiring centre · Conservation techniques

34.1 Introduction

34.1.1 An Overview of Agricultural Mechanization

Agriculture mechanization refers to the use of different power sources and improved farm tools, implements, and equipment to reduce labour; increase cropping intensity, yield, productivity, precision metering, and placement of inputs; and reduce crop losses at various stages of crop production. Mechanization requires a lot of capital investment. Investing in mechanization may not deliver the desired outcomes without proper planning and guidance. India's selective mechanization strategy makes agricultural mechanization difficult. This selective mechanization maximizes the use of agricultural resources. Rural landholdings benefit from better human and animal-drawn equipment. Large farms are being mechanized by tractor-drawn and self-propelled agricultural machines. It is necessary to implement a mechanized technique that achieves the demands of farmers.

Landholdings in different parts of the nation must be consolidated (virtual or actual) for their owners to profit from agricultural mechanization. So, timely operations and improvements in equipment and processes should increase quality and quantity in agriculture production. A lack of modern equipment and technology constraints Indian farmers. As a consequence, manufacturing costs are high, and export markets for surplus produce are limited. There are large technological disparities across cropping systems and regions. Using precise and efficient equipment will enhance the quality of processes including seedbed preparation, sowing, fertilization, chemical and irrigation water application, weeding, harvesting, and threshing. Mechanization has so far benefited wheat-based farming systems in India. These advantages must be extended to other agricultural systems, including rice and horticulture.

The availability and efficient use of agricultural electricity by farmers influence agricultural output. Agricultural machinery boosts land and labour productivity by speeding up agricultural activities and increasing output per unit time. The total farm power availability in the country was 2.24 kW/ha in 2016–2017 with a share of 1.324, 0.018, 0.021, 0.460, 0.193, 0.091, and 0.130 kW/ha from tractors, power tillers, combines harvesters, diesel engines, electric motors, humans, and draught animals, respectively (Mehta et al. 2019). In general, they reported mechanization levels of 46% for rice and 24% for sugarcane, wheat, and sorghum, respectively (Fig. 34.1). Small and marginal farmers who cannot afford to buy different agricultural equipment for various field operations now have choices due to the rising trend of establishing custom hiring and hi-tech centres in localities. Tiwari et al. (2019) estimated 3.74 kW/ha agricultural power availability in 2032–2034. They also

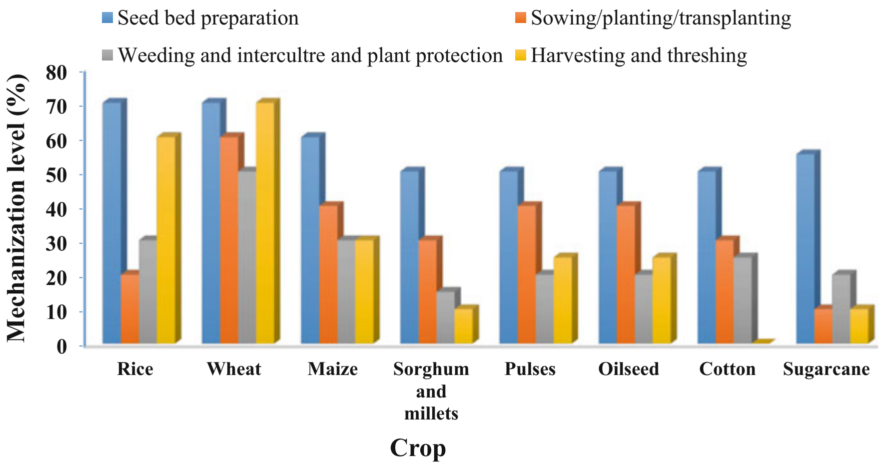

Fig. 34.1 Agricultural mechanization level for main crops in India. Reprint with permission taken from Modi et al. (2020)

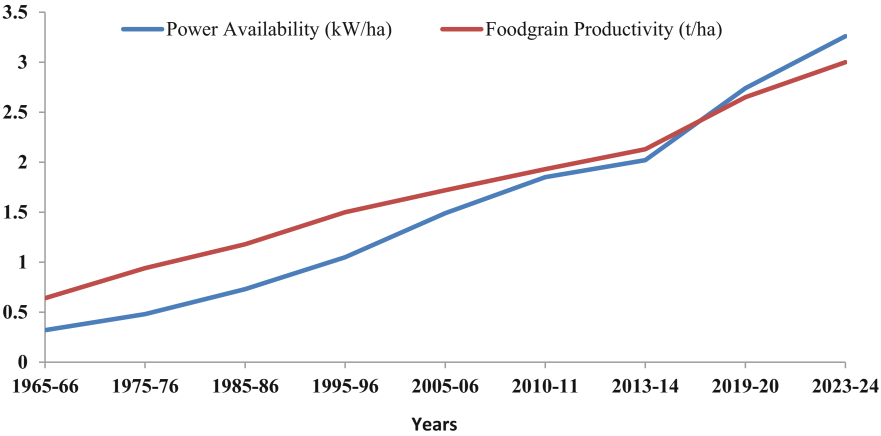

Fig. 34.2 Relation between power availability and food grain productivity during different periods. Data taken from source: DAC, GOI

estimated a decline in agricultural labourers from 54.6% to 49.9% in 2021 and 25.7% in 2050. The correlation between power and grain production is proportional (Fig. 34.2). Food grain productivity in the country increased continuously from 0.32 kW/ha in 1965–1966 to 2.74 kW/ha in 2019–2020.

Limited natural resources affect agricultural production systems. Inadequate management of these resources and their quality is also influenced by climate variability. Agriculture must be changed to promote sustainability and resistance to the consequences of climate change without compromising food security for all. These issues are interrelated and anticipated to be solved concurrently by smart agriculture. Agricultural mechanization would assist create a climate-resilient agricultural system and enhance earnings via increased agricultural production. Agricultural techniques are required in every region of the world. Arid land is land that is too dry for conventional rainfed agriculture. Millions of people live in such areas, and if present trends continue, millions more will shortly. These people need to eat; thus they should grow their food. However, the strategies are so diverse that only a huge volume could cover them all. Traditional practices may be tough to improve, yet sometimes even basic and economical advances may be revolutionary. This chapter suggests that one must begin to improve local agriculture in arid zones by learning what is already there and future mechanization techniques. Then both techniques and plants that may be useful in specific situations are suggested.

34.1.2 Status and Scope of Agricultural Mechanization in the Arid Region

Agricultural mechanization is critical for increasing input efficiency while also increasing output and productivity. Agricultural mechanization methods have been shown in several studies to enhance crop yield and productivity by 10–15%, as well as cropping intensity by 5–20%. It will also save up to 15–20% on seeds, fertilizer, and pesticides, as well as 20–30% on time and labour. In terms of the worldwide situation, Western Europe, the United States, Brazil, Russia, and China have achieved mechanization levels of 95, 95, 75, 80, and 59.5%, respectively (Grant Thornton 2017). On the other hand, India has only attained a mechanization level of 40% (Mehta et al. 2019). Haryana, Punjab, and Uttar Pradesh are the top states in India, while other states lag behind. The availability of agricultural electricity in Rajasthan grew from 1.14 kW/ha in 2014 to 1.37 kW/ha in 2017; however, it is still quite low when compared to the top states (Ministry of Agriculture and Farmers Welfare, Mechanization and Technology Division, GOI). Tractor adoption is on the increase, while other agricultural implements are still in the minority. Farm mechanization is constrained by the dispersion of farm sizes. Rajasthan state has a notably distinct pattern when compared to India's average farm size. On average, the size of a farm in this state is bigger than in the rest of India. Farmers who operate a field of up to 2 hectares account for 58% of all holdings, whereas on average, they account for 85% of total holdings. When compared to the national average, small, semi-medium, medium, and large landholdings account for a larger share (Table 34.1).

Table 34.1 Average farm size in Rajasthan versus India

Type of holding	India (%)	Rajasthan (%)
Marginal (< 1 ha)	67.1	36.5
Small (1–2 ha)	17.9	21.9
Semi-medium (2–4 ha)	10.0	19.4
Medium (4–10 ha)	4.2	16.4
Large (> 10 ha)	0.7	5.9

Source: Department of Agriculture Rajasthan (2011)

Reduced supply of agricultural labourers is predicted to drop by about 26% by 2050. Cooperative organizations, custom hiring centres, and farmer groups are all possibilities in today's Indian agriculture. Financial assistance to local manufacturers via the Make-in-India programme to build agricultural machinery or equipment that meets local needs rather than depending on imports from industrialized nations. Small-scale mechanization and custom-hiring centres are quickly becoming viable options for small-scale farmers.

The Indian arid zone covers 31.7 mha, with the majority of it in north-western India (28.57 mha) and some in southern India (3.13 mha). The Great Indian Desert, often known as Thar, included major portion of the arid regions of Rajasthan and minor portion of Gujarat, Punjab, and Haryana. The western Rajasthan encompasses around 61% of the country's total hot arid areas, making it the country's primary hot arid region (Tewari et al. 2014). Arid soil covers around 12% of India's geographic area. Rajasthan, Punjab, Gujarat, Haryana, Karnataka, Maharashtra, and Andhra Pradesh are all part of it. Overexploited vulnerable natural resources in India's arid areas are mostly under mixed farming, which is virtually exclusively rainfed with poor and unreliable yields. Crop yields in this zone are heavily influenced by the weather. The weather observed as irregular rainfall (100–450 mm) and extreme temperatures (usually>45 °C in peak summer and sub-zero in winter) and high summer winds of more than 30 kmh^{-1} during summer. These are the ever-present climate issues, particularly for agriculture. Cropping in the Indian arid areas has always been seen as subsistence rather than a commercial operation due to socio-economic conditions. Most farmers in subsistent farming resort to producing certain rainfed crops on farm solely to meet their household requirements and rotate a specific crop mix over 3–4 years. That results in multitude of cropping systems which are constantly changing in location and time, making it impossible to accurately evaluate the distribution of various cropping systems across a larger area using the conventional method.

The opportunity for growth in Rajasthan would be severely limited unless agricultural production risks are minimized. Soil moisture management is the single most significant aspect in lowering the risk. With the region's limited surface and groundwater resources, further extension of conventional irrigation with poor water yield will be impossible. Prerequisites for the growth of the region's agriculture include soil moisture conservation, precise irrigation to achieve the maximum potential water productivity, and utilization of the limited water supply for the high-value crops. In rainfed regions, coarse cereal crop production will continue to dominate due to its capacity to survive in drought and low water requirement. It is necessary to incorporate equipment and technology for the planting, harvesting, and threshing of coarse grains such as pearl millet. It is necessary to plant seeds deep in the soil to take advantage of the depleting soil moisture. Farmers in the region should have access to sufficient power and matching equipment for timely land preparation and precision planting of various coarse cereals and other rainfed crops of arid region. Also, to make the efficient utilization of soil moisture available for crop establishment stage before the soil top layer dries out. To maintain agricultural production in arid areas, suitable mechanization methods matched to the requirements of farmers must be adopted.

34.1.3 Rajasthan Government's Initiatives for Farm Mechanization

The last two decades between 2000 and 2010 was a period with a major boom in agricultural machinery manufacturing for mechanization. In these decades, John Deere, Mahindra & Mahindra (M & M), New Holland, and Tractors and Farm Equipment Limited (TAFE) built their manufacturing units in India, and the Indian manufacturers started operations overseas in rural areas of our country as well as our state. In addition, according to Singh (2015), the implementation of the new scheme of our country Mahatma Gandhi National Rural Employment Guarantee Service has had a tremendous socio-economic impact on agricultural labour and improvement in their social status. This situation has offered a considerable boost to mechanization.

Rajasthan Agriculture is witnessing a significant movement from manual to mechanical power; the shift is mainly because of unavailability and the high cost of labour at farms. Further, the mechanical power directly influences the quality of farm operations which in turn increases the crop productivity, timeliness of agricultural operations, and reduction in drudgery. In November 2016, the Government of Rajasthan (GOR) signed an agreement with EM3, TAFE, and Mahindra & Mahindra to set up, launch, operationalize, supervise, and certify Custom Hiring Centres (CHCs) across Rajasthan. In this context, EM3 is responsible for establishing more than two hundred centres according to mass to provide mechanization services to one lakh farmers in 28 districts of the state. EM3 works with different business models in the states where it operates. In the case of Rajasthan, the start-up has decided to work with a franchise model to procure the equipment required to fill the existing machinery and technology gaps in the state. In addition, Tractors and Farm Equipment Limited (TAFE) has set up JFarm Rajasthan, an advanced agricultural research centre in Bhawani Mandi, Jhalawar District, in November 2016, which will facilitate the farmers of Rajasthan to hire tractors and modern farming machinery. TAFE has entered into an agreement with the government to set up CHCs in six identified zones (Bharatpur, Jodhpur, Jaipur, Jalore, Kota, and Sikar) across the state (TAFE 2017). TAFE's agreement with the Government of Rajasthan focusses on two initiatives – Custom Hiring Centre and JFarm. Rajasthan Center of Excellence with an estimated total cost over five years. Through agreements worth Rs 970 crores with the Rajasthan government in the agriculture sector of Rajasthan, JFarm Services expects to partner with 900 farmer entrepreneurs, create 4000 jobs, and touch the lives of 500,000 farmers.

The implementation of the Sub-mission on Agricultural Mechanization (SMAM) program by the Ministry of Agriculture is therefore a step towards ensuring last-mile reach of agricultural mechanization to small and marginalized farmers (Government of India 2018a, 2018b). Apart from SMAM, the government also promotes agricultural mechanization programs through other missions/schemes like Mission for Integrated Development of Horticulture (MIDH), Rashtriya Krishi Vikas Yojana

(RKVY), and Oilseeds and Oil Palm (NMOOP) (Government of India, National Mission) (Government of India 2016–2017). However, CHCs for farm implements were set up in 100 NICRA villages which could successfully empower the farmers to overcome the labour shortage and improve the efficiency of agricultural operations. A committee of farmers nominated by the Gram Sabha manages CHCs. Rates for hiring machines/tools are set by the Village Climate Risk Management Committee (VCRMC). The committee also utilizes the proceeds from the hiring charges for the repair and maintenance of the equipment, and the rest goes to the revolving fund. 27 different types of agricultural machinery are stocked in 100 CHCs. The most popular are rotavator, zero till drill, drum cider, multi-crop planter, power weeder, and chaff cutter. Each centre was set up at a capital cost of Rs. 6.25 lakhs funded by the NICRA project. As a result of government initiatives and equal participation of the private sector, agricultural mechanization has been steadily increasing in recent years, which can be seen in the increase in production, sales, and export of tractors from the country. CHCs and innovations in the agricultural machinery sector, therefore, have the potential to drive the next phase of agricultural development in India. Thus, there is a need for a congenital policy framework to encourage setting up of community health centres as the preferred business model in the country so as to efficiently bridge the gap between need and availability. Increasing awareness and knowledge of farmers through various stakeholders in the agricultural supply chain and involving farmers' investments in implementing future plans and policies can lead to better value creation.

34.2 Farm Mechanization in the Arid Region

Farm mechanization includes machinery involved in farm operations, viz. tillage, sowing, transplanting, fertilization, weeding, irrigation, protection, harvesting, threshing, waste management, and transportation. Some of the machinery, tools, or implements have been recommended for arid regions as presented in Table 34.2. These agricultural implements may be utilized in arid region for efficient utilization of input resources for crop production and productivity.

34.2.1 Tillage

Tillage is one of the operations for manipulating the soil mechanically. It's required for weed control and to bring out the optimum tilth and physical environment of soil for crop establishment and proper germination. In this context, soil tilth is meant for the physical condition of the soil describing its cone index, bulk density, roughness, porosity, and structure related to nutrient, water, air, and heat transport. Tillage is highly mechanized (exceeding 50%) for major crops of India (Mehta et al. 2019). It is usually categorized as primary and secondary and depends largely upon the rainfall and soil type. Some of the methods have been described hereunder.

Table 34.2 Details of agricultural machinery, implements/tools of the arid region

Operation	Agricultural implements and machineries
Tillage	
Tractor	Mould board plough, disc plough, tyne type cultivator, disc harrow, rotavator, pulverizing roller, cultipacker, cage wheel
Power tiller	Rotavator, mould board plough, cage wheel
Animal	Mould board plough, camel-drawn 2 and 3 tyne plough, ridger, camel-drawn harrow, blade harrow, disc harrow 6 disc, harrow patela
Manual	Pick-axe, spade, trenching hoe, garden rake
Land levelling	
Tractor	Tractor-drawn leveller, laser-guided land leveller, scraper, planker (Pata), variable width raised bed former
Animal	Camel-drawn bund former, buck scraper, clod crusher
Manual	Spade, scraper
Sowing and fertilizer	
Tractor	Seed drill, seed cum fertilizer drill, maize planter, groundnut planter, cotton planter, fertilizer broadcaster, zero till drill, strip-till drill, rapeseed-mustard seed drill, ridge planter for maize, ridger seeder, multi-crop planter, pneumatic precision planter, mulcher-cum-bed planter, vegetable transplanters, small seed planter, broad bed and furrow (BBF) planter, furrow irrigated raised bed (FIRB) planter, turbo happy seeder, garlic planter, turmeric rhizome planter, BT cotton planter, ridge fertilizer drill cum seed planter, semiautomatic vegetable transplanter
Power tiller	Lightweight multi-crop planter, site-specific fertilizer applicator
Animal	Camel-drawn seed cum fertilizer drill 2–3 rows, seeding attachment over deshi plough, maize planter, groundnut planter, cotton planter, indigenous seed drill, CRIDA drill plough, Jyoti multi-crop planter
Manual	Dibbler, push-type seed cum fertilizer drill, seed drill
Weeding and intercultural	
Tractor	Cultivator, cultivator with duck foot shovel, high clearance weeder, garlic weeder, rotary weeder, mechanical intra- and interrow weeder
Power tiller	5–7 tined cultivator, self-propelled power weeder, sweep tyne cultivator
Animal	3–5 tined cultivator, ridger, improved bakhar
Manual	Wheel hoe, V-blade 3 tined hoe, kudali, power weeder, dryland peg weeder
Irrigation	
Tractor	Irrigation channel former, subsurface drip laying machine, drip lateral-cum-plastic mulch laying machine
Power tiller	Irrigation pump attachment
Animal	Plastic mulch laying machine, Persian wheel, duplex pump
Manual	Diaphragm type low lift pump
Plant protection	
Tractor	Real-time uniform sprayer, mini tractor-operated field sprayer, centrifugal prayer, aero-blast sprayer, boom sprayer, motorized knapsack power sprayer cum duster, ultrasonic sensor-based pomegranate spraying system
Power tiller	Sprayer attachment

(continued)

Table 34.2 (continued)

Operation	Agricultural implements and machineries
Animal	Solar-powered sprayer, sprayer attachment
Manual	Knapsack sprayer, hand compression sprayer, backpack sprayer, foot sprayer, duster, wide-swath spray boom for tall crops, solar-powered bird scarcer
Harvesting	
Tractor	Vertical conveyor reaper, cotton picker, reaper binder, tractor-drawn combine, groundnut digger, millet harvester, cotton stalk puller, hydraulic-operated pigeon pea harvester, cassava harvester, straw reaper, straw baler
	Self-propelled reaper binder, combine harvester, straw combine, scythe
Power tiller	Carrot harvester cum detopper
Animal	Groundnut digger
Manual	Improved sickle, sugarcane stripper
Threshing	
Tractor	Multi-crop thresher, maize dehusker cum sheller, single row corn cob picker
Power tiller	Multi-crop thresher
Manual	Pedal-type paddy thresher, groundnut stripper, tubular maize sheller, burr-type maize sheller, pedal-operated maize dehusker sheller, winnowing fan
Straw management	
Tractor	Wheat straw collector, cotton stalk shredder-mixer, paddy straw bale shredder-cum-mulcher, baler
Animal	Bullock drawn chaff cutter, camel-drawn chaff cutter
Manual	Hand chaff cutter
Transport	
Tractor	Trolley, trailer
Power tiller	Trailer
Animal	Camel cart, bullock cart, 4-wheel camel cart, 2-wheel camel cart with jeep tyres
Manual	Hand cart with solid rubber wheel

Sources: Ministry of Agriculture and Farmers Welfare, Mechanization and Technology Division, GOI; ICAR-CIAE annual reports (2014–2019); Singh et al. 1998; Jangid et al. 2010; NRC on camel report (2003).

In western parts of Rajasthan, the harrow is commonly used with patela for tillage operations. Conservation tillage is another method for conserving water, soil, and energy by reducing the tillage intensity and mulching of crop residues. It has different types, viz. zero till, mulch till, strip-till, and ridge till. It is associated with the minimum disturbance in soil in seeding, growing, planting, and harvesting of the crops. Zero tillage/no-tillage is one of the alternatives to conventional methods for seed bed preparation. It increases the carbon content at top soil (Lenka and Lenka 2014). Rotary tiller helps in mixing fertilizer or manure while mixing weeds with the soil. Rotavator has reduced the operation time and cost by 30–35% and 20–25%, respectively (ICAR 2007). The simultaneous operation of two or more tillage implements is referred to as the combined tillage. Combination tillage reduces soil compaction, the time required for field operation, labour cost, and fuel cost. The time and cost reduction have been estimated as 50–55% and 44–55%, respectively, during seed bed preparation (Prem et al. 2016). It has a performance index higher than the same for conventional tillage. Laser levelling is used for very fine levelling of the agricultural field with the application of laser, which helps enhance the crop yield. Cook and Peikert (1960) reported it is helpful in reducing the irrigation water requirement by 20–25%. A controlled wheeling system becomes advantageous in terms of extra output with a reduction in variable cost. McCrum et al. (2009) reported it is useful in reducing the power requirement by 30% as a result of improvement in soil structure. So, these are some mechanized tillage and land levelling operations that can be used in arid regions for efficient utilization of natural and input resources for crop production.

34.2.2 Sowing/Transplanting

Sowing or transplanting is one of the operations intended to have desired crop yield. It becomes difficult to operate manually due to labour shortage in the specific period of the operation. The crops may get affected if sowing or transplanting is delayed. Thus, mechanization plays role in precision, timeliness of operation, cost-effectiveness, and input efficiency with resource conservation. The technologies commonly used in the arid region have been enlisted here in Table 34.2.

However, tractor-drawn three-furrow (six-row), multi-crop seed cum fertilizer drill has been developed for sowing the crops on slant surfaces especially with a created furrow with seed-pressing device (Fig. 34.3). The furrows are meant for

Fig. 34.3 Tractor-drawn seed cum fertilizer drill for sowing the crops on slant surfaces

collecting the runoff water for maintaining high moisture concentration in the plant root zone. It resulted in an increase in plant height and grain yield by 26% and 30–70%, respectively, as compared to the same for the conventional method. The grain yield could be increased by 30–40% as compared to the same with the conventional method for green gram, moth bean, pearl millet, and cluster bean crops with normal rainfall of 389.3 mm/year. However, the increases in grain yield have been recorded up to 60–70% with severe moisture stress during kharif (Singh et al. 2007). This technology has great potential of getting popularized for improvement in crop production of the arid region.

34.2.3 Weeding and Intercultural Operations

Weed control is targeted to reduce the competition of crops for nutrients, water, and sunlight. Some of the improved weeding tools are peg tooth weeder, slotted hand hoes, and two/three tyne animal-drawn shovel. Mechanical weeding is recommended before applying the chemical method to eradicate the weeds and make water availability to the crops. The yield loss is associated directly to weed competitiveness. Rao and Chauhan (2015) estimated yield losses in India as 10–100% (Fig. 34.4).

As the arid region is having light-textured soil, a pull-type weeder is conveniently used manually. Traditional Kassi is usually used in the region. It has problems of high pull requirement (8.5 kg_f) and removal of worked soil from the blind face of Kassi. The field capacity was found maximum with double slot weeder as 193.4 m^2 ha^{-1} with 94.5% as the weeding index. Their respective values were 165.3 m^2 ha^{-1} and 98.5% for single slot weeder whereas 160.5 m^2 $h^{-1}$and 91.8%

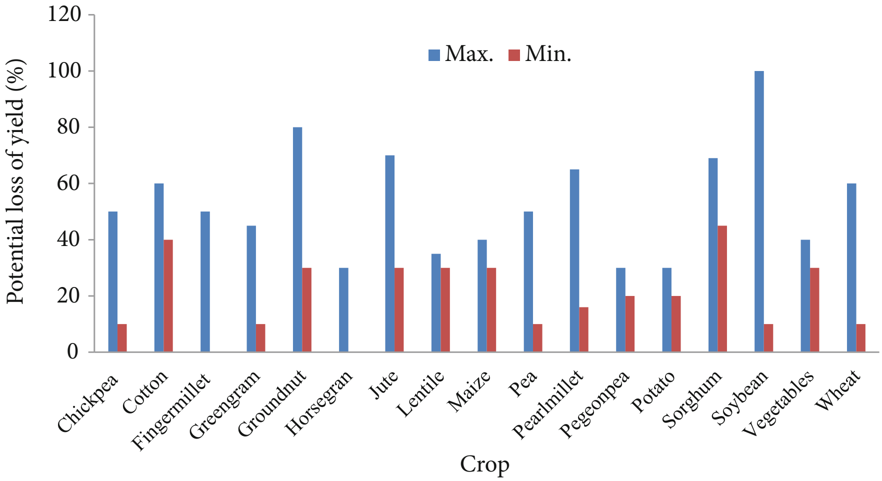

Fig. 34.4 Maximum and minimum potential yield loss due to weeds in major crops of India. Data obtained from Rao and Chauhan (2015)

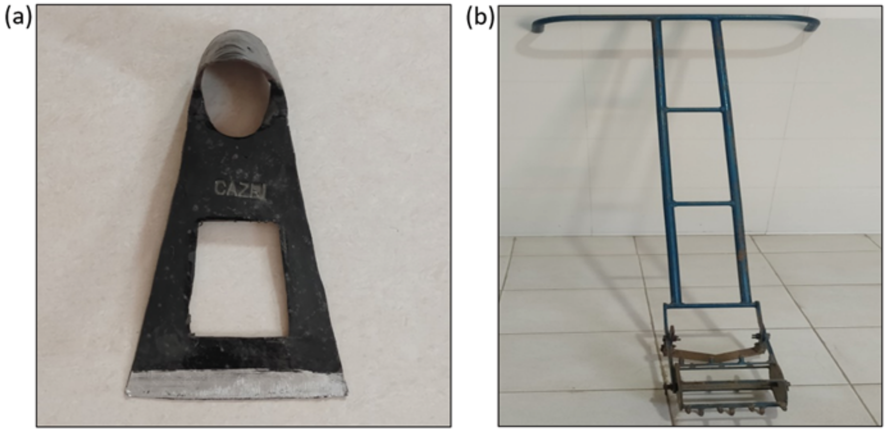

Fig. 34.5 (**a**) Improved Kassi; (**b**) crust breaker

for traditional Kassi. The problem of soil accumulation was resolved through an appropriate slot made in the blind face of Kassi. It could reduce the pull requirement by 40% and thus suited to women and younger farmers. Weeder was found best suited to men with 130 mm width, which requires 65% power with 20% greater field capacity as compared to the traditional Kassi (Fig. 34.5a). Single slot Kassi has preferably been used due to its convenience in operation.

The germination is affected due to crust formation in the soil as a result of sand deposition at the upper surface of the field. This problem could be resolved using a manually operated crust breaker. It consists of a peg type wheel followed by a blade for uprooting the shallow weeds with a long handle (Fig. 34.5b). It is operated manually between two rows of crops in a standing position through push and pull action. It cuts weed while creating soil mulch by breaking the soil crust. The sharp pegs penetrate the upper layer of soil and resulted in a break in the hard crust. Thus, the rear blade helps uproot the weeds. It requires 90 man-hours for crust break operation of a one-hectare area with 78.9% of the weeding index and 3.8% of minimum plant damage.

The mechanical weeding tools, viz. hand hoes, animal drawn weeders, power weeders, manual operated push-pull-type weeders, and tractor-operated row crop cultivators, are used in crop rows for weeding the plants. The conventional weeding methods are time-consuming, laborious, and costly, and thereby various researchers have aimed to mechanize the operation. The intercultural operation in the horticultural crops seems difficult due to its crop canopy and reach of the regular implements. A tractor-mounted offset rotary tiller or rotavator is an implement which can be used for the pulverization of soil as a secondary tillage operation as well as weeding purposes in fruit tree orchards and agroforestry fields. Using an offset rotavator makes it easier to remove weeds under and around a plant canopy. This allows us to do inter-cultivation operations in an efficient way which leads to saving time as well as drudgery. The era of intelligent weeders has come with sophisticated ways for controlling the weeds and leaving crop plants undamaged. This includes innovative technologies, viz. machine vision, robotic weed control systems, and RTK GPS guidance systems intended for a significant reduction in weeding time and drudgery.

34.2.4 Irrigation

Water is an important resource for plant breeding and living in arid regions. It leads to the adaptation of very few species with increased aridity and reduced biomass. Plants are thus recommended to be grown in an arid region with the help of some of the mechanisms. Due to scarcity of water, it is difficult for plants to compete with weeds. Water quality is another problem of the arid region resulting in soil salinity and thereby limiting crop production. Thus, water management of the region encompasses water collection, conservation, and efficient utilization while avoiding its losses through infiltration or runoff.

India is a vast country with wide variations in rainfall patterns with the occurrence of drought in some parts of the country. A large portion (65%) of the country is practicing rainfed agriculture (Singh et al. 2013). Thus, water use efficiency is always of prime concern for researchers of different disciplines. In the event of inadequate rainfall, water is poured into the soil through artificial application for crop cultivation, habitat preservation, and improving the degraded soil in the arid region. It encourages adapting the irrigation system for crop plants with reduced cost and wastage of water. Mechanization of irrigation system is thus required to take care of the wastage through evaporation, seepage, and deep percolation. It leads to micro-irrigation systems as modern methods of irrigation. A micro-irrigation system is in demand due to its association with a significant reduction in water wastage. Government schemes are also encouraging it to adapt through subsidy. It is usually categorized as sprinkler system, surface system, and drip system. The sprinkler system is operated in the form of spraying water using the overhead sprinklers, whereas the drip irrigation system is the water application in the plant root zone.

Dryland farming is an important component of the growth of Indian agriculture. Phule check basin has been found to contribute tremendously to the dryland farming of Maharashtra through rainwater harvesting. The check basin of 6 m × 2 m size assists for 30–40% timeliness with 50–60% saving and increased production in the rabi season (Turbatmath and Deshmukh 2016). As groundnut yield is declined by 10–15% in the rainfed condition due to delay in sowing by 1 week, the aqua planter has been designed and developed to resolve the issue (Laxman et al. 2018). It ensures seed sowing with simultaneous application of required water for germinating the seeds. Thus, the technology is advantageous for dryland farming. Integration of an aqueous fertilizer tank with the aqua planter can improve germination and crop growth at initial stage rainfed conditions. It is powered by a 45 hp. tractor with a field capacity of 0.25 ha/h. The machine consists of liquid fertilizer tanks (2pcs), a fluted roller seed metering mechanism, and a constant head central tank. Wheat cultivation has been investigated with the increase in germination and yield by 53 and 35%, respectively. Water absorption increased by 350 times using the hydrogel to make water available to the plant roots in the stress condition. The hydrogel applicator can also be attached to the aqua ferti seed drill or seed cum ferti seed drill (ICAR-IARI 2022).

34.2.5 Plant Protection Operations

Chemical application is practiced for saving crop plants from insects, weeds, and diseases. It may be in either the form of dust, spray, or mist. The chemical application requires efficient equipment for its judicious use due to health issues and the cost involved. A duster is simple and commonly used for chemical applications and best suited to portable equipment. However, sprayers are more efficient as dust has less retention capacity. It is used for various applications, viz. insecticides, herbicides, micronutrients, and protective fungicides. Sprayers are meant for splitting liquid into droplets and distributing the same uniformly over the space or surface to be protected. It is useful in regulating the operation to avoid excessive application of chemicals. Sprayers of different types have been designed and developed for the specific crop and field. Some of them are foot sprayers, knapsack sprayers, hand compression sprayers, twin knapsack sprayers, motorized knapsack mist blower cum duster, and centrifugal rotary disc-type sprayers. Presently, ultralow volume sprayers are in practice for the application of concentrated pesticides with the help of special nozzles and the development of new formulations. Controlled droplet application atomizer is considered suitable for arid regions due to ease of operation and requiring spray mixture less than 15 L/h.

The chemical applicators may be integrated with solar photovoltaic cells for power requirements. In a study, the sprayer achieved 84 L/h of application rate with 0.21 ha/h capacity, but the same was varying with solar irradiation (ICAR-CAZRI 2016–17). Dusters are also linked to solar power for application in the arid region of Rajasthan. The recent advancement in technological intervention has reached the era of sensor application for identifying and monitoring the infested location, infestation level, and GPS-mounted sprayers. Thus, precise application of pesticides leads to effective control of pests with saving of pesticides as compared to the conventional method of pesticide application (Dworak et al. 2013). Autorotating-type gun sprayer is recommended for efficient and effective spraying at the rate of 375–1000 litres per hectare with 30 min wide swath and 3–4 ha/h capacity for controlling the sucking pests, viz. whitefly in cotton.

It is still difficult to spray the chemicals as one has to walk through the standing crop and thereby high clearance vehicles are used. PAU (Punjab Agricultural University, Ludhiana) has developed a sprayer consisting of autorotating gun with boom and drop up type of mechanism. It can spray effectively at all stages of crop growth with high clearance. A tractor is also developed with high clearance and narrow rear tyres for mounting the spraying systems. The high clearance sprayer has field capacity and breakeven point of 1.78 ha/h and 300 ha/year with labour, time, and cost savings up to 95, 95, and 66%, respectively, as compared to the knapsack sprayer (Singh et al. 2018). Electrostatic spraying has subsequently improved the efficacy and spatial distribution of droplets throughout the plant canopy. The air-assisted electrostatic sprayer has been developed as a mobile backpack (MBP) type with 5 hp. engine and a non-board compressor. A spray gun is also developed with 9.0 V rechargeable batteries (2 Nos.) to charge the spray particles. It can increase the spray deposition on the upper side and underside by 80 and 85%, respectively, as compared to the knapsack sprayer. Electrostatic sprayer drift loss is 50% lesser than the same for knapsack sprayer. Bio-efficacy, the percentage of insects killed, has been estimated 68% higher than the manual operated knapsack sprayer (Singh et al. 2018). However, recent advancements comprised drone application and spraying attachment (Kumar et al. 2018). These technologies are recommended for the efficient application of pesticides in the arid region.

34.2.6 Harvesting and Threshing

Mechanization index in harvesting and threshing operations increases up to 60–70% for rice and wheat, but for other crops, it is less than 30% (Mehta et al. 2019). Around 5000 combine harvesters are sold annually in India. Indigenous models are of Standard, Kartar, Dashmesh, and Preet companies, while foreign manufacturers like Kubota, CLAAS, and John Deere are also exporting their developed combine harvesters in different regions of India. Combines may be tractor drawn or self-propelled type. Track- and wheel-type self-propelled combines are commonly used. Track-type combines have good traction to work in sticky and wet-type soil for harvesting in the south.

About 90,000–1, 00,000 threshers are sold annually in different parts of India. Manufacturing of threshers is done by huge amount of small- and medium-scale enterprises (SMEs) situated in the state of Punjab, Haryana, Gujarat, Uttar Pradesh, Madhya Pradesh, Maharashtra, Bihar, Andhra Pradesh, and Tamil Nadu. The thresher market is likely to develop at a compound annual growth rate (CAGR) of 10 per cent. Threshers are applicable in hilly terrain or other difficult areas or marginal farmers that are unable to recompense the cost of operation by the combine. There are different types of threshers available in the Indian market like wheat thresher, basmati thresher, paddy thresher, and multi-crop thresher for efficient threshing of crops with the minimum grain damage. Multi-crop threshers are used for the threshing of soybean, millets, oats, wheat, barley, sorghum, chickpea, and pulses. Threshers are operated with a 35–70 hp. tractor or electric motor of 7.5 hp. or a diesel engine of 10 hp. and give grain output capacity of about 1200–2500 kg/h. Ergonomics is applied to some design modifications in harvesting and threshing machinery to make them ergonomic for human use and adoption as per region-specific requirements.

34.3 Socio-Economic Aspect of Farm Mechanization

34.3.1 Drudgery Involved in the Farm Operation

Agricultural activities are performed in an unfavourable ergonomic posture, including repetitive body movements, long periods of operation, machine noise and vibration, etc. that may cause musculoskeletal diseases, awkward posture, and discomfort. Agricultural machinery should be designed and manufactured to be safe when used properly. The machine should be operated and maintained following the manufacturer's instructions. Machines should be equipped with safeguards or secure storage for potentially hazardous parts. In addition to the amount of physical and mental workload, stress and exhaustion are also associated with variables such as posture, environmental parameters, and certain psychological factors. Inadvertent disregard of ergonomics in the design, development and various instruments operation, and machines has resulted in many injuries and fatalities in various agricultural operations. Particularly in conventional agriculture, there are concerns about difficulties, drudgery operations, slow work processes, and other work organization challenges (such as basic tools and procedures) where ergonomics can help by contributing to aspects of work efficiency and product justification. Because technologies apply high physical stress, they should not be applied. However, there are occasions where ergo-design benefits health and comfort.

Various agricultural research institutions/industries have designed, developed, and promoted several improved implements to reduce the drudgery of various agricultural activities performed by human labour. However, only a few respondents in the research area owned them. The knapsack hand sprayer took first place among the improved manual operated equipment owned by respondents, with 12.24%, followed by foot sprayer (1.69%), groundnut decorticator (1.27%), and duster (0.42%). Even though maize is the most significant kharif crop in the area, none of the respondents had improved sickles or maize cob shellers (Jangid et al. 2010). Having solutions in place that satisfy design and operating requirements is important for machinery and equipment safety. Machine designers/developers and manufacturers are responsible for design requirements. Users are accountable for providing harmless working surroundings for their work and must meet operating standards. Machines and equipment should be developed, manufactured, and operated following machine functioning and intended usage to ensure that equipment and machineries can be serviced and modified safely. Such requirements include ergonomic criteria. They ensure the proper functioning of human users and operators of technical equipment. Design-related requirements are a top priority for safety. While they promote the use of technological equipment, safety ultimately depends on meeting specific operational criteria (Górny 2017). Work requires resources that allow it to be done without undue strain or hindrance. Workplace resources include tools and equipment (Gite et al. 2020). The knowledge of people's psychological and physical abilities is an important necessity for machine and equipment design. These requirements ensure the safety of operation once satisfied. It includes the correct equipment design and development.

Given the fact that operators must operate machines in the field, ergonomics considerations during the application of agricultural equipment are extremely important for them to consider. Because ergonomics contributes to the creation of human comfort, it will help the operator successfully operate the machine while delivering the required level of productivity. To improve operators' performance, the workplace on agricultural machinery needs to be comfortable and safe. During agricultural operation, frequently operated controls should be within the reach of the operator for easy and comfortable operation, a reduction in physical workload, improving the working efficiency, and preventing accidents (Shukla et al. 2021).

34.3.2 Cost-Economics of Agricultural Machineries

As presented in different studies, direct relationship between farm mechanization and crop yield. Farm mechanization helps in many input savings and increased cropping intensity. An arid and semiarid region of Rajasthan state, rainfall pattern varies abruptly, so timely sowing is most important to increase crop production efficiency. The cost of deploying labour for agriculture operation is increasing substantially. Farm mechanization is the only alternative to dealing with the increasing cost of labour and timeliness of field operations. Survey work among farmers has revealed that nowadays majority of farmers are using tractors for agricultural operations on their land. Even then, they have to use camels for ploughing some of the portions of their land which cannot be covered by a tractor, viz. sand dune portion. Apart from that, if the sand storm comes and one needs to plough, the camels are used for that purpose. Some of the farmers exclusively use camels for agricultural operations. Single and double plough shares are used in large amounts. Sowing of groundnut requires both tractors and camel. Initially, the tractor is used for pulverizing the soil, which is then sown with a camel. A camel can plough 0.76–1 hectares land in a day. Putting more labour, it can be possible to cover even 1.52 hectares of land. In groundnut sowing on land previously pulverized with a tractor, a camel can cover only 0.25–0.38 hectares in a day. Camel has been an extremely useful animal of the desert, which can be used in multifarious modes of functions such as pack animal, to pull cart, to pull agricultural implements, and for riding purposes. As a pack animal, it can bear a load equal to 225–295 kg and travel 32 km in a day at a speed of 3–4.5 kmh^{-1}. It can pull a camel cart with loads of 18–20 quintals for 20–30 km in a day. Riding for a distance of 30–40 km can be accomplished per day (ICAR-NRC on camel 2003).

An analysis has been done on cost-economics of the tractors and animal use power for agriculture in the arid region. It was shown that nearly 50% of the area is sown by tractors, 26.36% by camels, and 18.5% by bullocks. Coverage varies with the number of days of use of animals and tractors. The benefit-cost ratio for a tractor, a camel, a single bullock, and a pair of bullocks has been estimated at 1.39, 1.06, 0.85, and 0.86, respectively, for maximum utility by considering agricultural and transportation operations. Similarly, the benefit-cost ratio for a tractor, a camel, a bullock, and a pair of bullocks were found at 1.52, 1.43, 1.3, and 1.07, respectively, considering the owner himself is the operator (Singh et al. 1995). The results are indicative of the significance of tractor and animal power in arid regions. The main factors affecting tractorization in the region were irrigated areas and draught power. Tractorization of agriculture can get a fill in the region with irrigation and significant reductions in draught power as well as profitability for crop production.

34.4 Future Mechanization Pathway through IoT-Based Technologies

Currently, agricultural technology serves as a feeder for consumers. A paradigm shift in agriculture requires innovative approaches to agricultural mechanization to maximize productivity. One approach is to use accessible IT in the context of smart devices, increasing and achieving energy output more efficiently than ever before. On the other hand, precision farming has proved to be effective; now is the time to move towards a new generation of equipment/mechanization. Although existing human operations are effective in large areas, there is potential for increasing the size of autonomous system services that can contribute to improved efficiency. Therefore, adherence to realistic precision approaches in agricultural machinery along with other measures to improve agricultural productivity from 140 mha of restricted cultivable land under the scarcity of natural resources and climate change problem to feed growing population (NAAS 2016). This will enable immediate measures to encourage agri-service providers to avail the benefits of agricultural mechanization from small and marginal farmers through farmers' cooperatives/custom hiring centres/machinery banks. The introduction of autonomous AI architecture enhances the potential to build a whole new range of agricultural machinery based on smart machines that can function properly. The adaptation of these technologies should be commensurate with the complexity of the actual situation and the environmental conditions/climate-smart in the agricultural production scenario. Some of such technologies are described below for agricultural sustainability in arid regions.

34.4.1 Mechatronics

Mechatronics systems are used in various application fields, like agriculture, automobile, safety, lifestyle, consumer goods, etc. Mechatronics is a collaborative combination of mechanics, electrical, electronics, computers, and control systems. Mechatronics has many useful uses in farming systems. Mechatronics components, such as actuators and sensors, play an important role in vegetation monitoring as well as in sowing, harvesting, and fertilizer application. The use of IoT in agriculture is pushing the boundaries of the mechatronics engineering stream beyond traditional methods. Some mechatronics applications can be used in automatic sowing methods, application of pesticides, and weeding applications. Mechatronics-assisted metering system in seed drills/planters can eliminate many of the inefficiencies experienced in a mechanically operated seed measuring device and have the potential to increase crop yield and productivity dramatically on tillage and no-tillage lands. The mechatronics-based system observed good seeding uniformity among all seeding technologies with quality of feed index, missing index, multiple index, and precision index in the range of 90–98, 0–11, 0–7, and 1–22%, respectively, under the speed of 1 to 16 km/h (Gautam et al. 2019). In this way, current and future mechatronics are being developed on the basis of technological advances required to extend and build human life easier and sustain the world.

34.4.2 Precision Agriculture

Precision agriculture has revolutionized the agricultural production sector in recent decades. It is a newer field of agriculture that focusses on optimizing input efficiency while maintaining production and involves vast amounts of data, such as field reference points, control variables, time, state, and meteorological data. These machines demand trained personnel and computer experts for their operation, care, and maintenance. Smart agriculture is the advancement of precision agriculture, in which farm management is remotely controlled by alternative relevant solutions in real time. It mentions the use of new technological innovations in agriculture to improve crop quality and quantity and enables observing variations in climate, soil moisture, and different soil properties. Smart irrigation, fertilization, and spraying improve the quality of produce, fertilizer management, and disease prediction in crops. The smart irrigation system has smart controls, sensors, and mathematical relationships for the measurement of water level, irrigation efficiency, and climate. IoT technology can connect remote sensors like robots, ground sensors, unmanned aerial vehicles (UAVs), and drones, allowing components to be linked together and controlled automatically for real-time harvesting, seedling, weed identification, irrigation, pesticide spraying, livestock applications, etc. (Mohamed et al. 2021). Also, Kumar et al. (2018) observed that Indian agriculture has the potential to use satellite navigation (SN) which can increase agricultural productivity. The risk of overlapping areas or missing areas is reduced with this technology, as it is a climate-smart approach to dealing with seasonal disasters.

Many obstacles (like soil salinity in dry areas) hinder agricultural output, reducing crop yields (Mohamed et al. 2021). Climate change influences agriculture yield and quality and may increase soil vulnerability to desertification. Global population growth and limited land holdings have prompted researchers to investigate the Internet of Things (IoT), artificial intelligence, machine learning, and robotics for economically viable, ecologically safe, and sustainable agriculture. Experts are now examining the possibility of developing more logical and flexible robotic systems based on external environment reactions. Orchards and horticultural crops such as oranges, strawberries, and tomatoes are already tested with unmanned remotely operated prototypes. Weeding, spraying, and harvesting robots with cameras and global positioning systems (GPS) have been tested. Also, robotic automated systems have been investigated for automatic feeding and cleaning in an indoor animal production system. Aside from existing precision agriculture approaches, current research shows that the deployment of autonomous tractors and robots in the agricultural farm has lowered farm labour and input costs (Jyoti et al. 2020). The IoT connects sensor devices to perform simple functions. Smart agriculture might be beneficial in dry regions to increase agricultural production with minimal inputs. Some of the benefits are as follows:

- More real-time agricultural data.
- Monitoring and controlling agriculture operations remotely.
- Managing water and natural resource.
- Better livestock management.
- Improve agriculture productivity by evaluating soil and crops properties.

Mohd et al. (2014) developed a web-based geospatial decision support system-graphical user interface for paddies called Soil Water Assessment and Management. For this, data on water irrigation requirement, water productivity index, and irrigation efficiency were provided. This technology provides real-time information by visualizing the outcomes. Palombi and Sessa (2013) established climate-smart agriculture (CSA) technique, to address food security, adaptation, and mitigation. In underdeveloped nations, CSA offers a lot of opportunities to increase food security and resilience agricultural system while cutting emissions of greenhouse gas. This is critical in developing nations since agricultural expansion drives economic growth and is most vulnerable to climate change (Mohamed et al. 2021). The European Union stressed the application of agricultural robots, sensor nodes, and UAVs for the collection of quality (high resolution) satellite images that might be incorporated into the smart agriculture initiatives agreed by 24 EU nations in April 2019 (Bacco et al. 2019). With the expansion of sensing systems for data collection, processing, and analysis, the data utilized in agricultural management has grown rapidly. Thus, a cloud server-based technological network necessitated linking all smart network components at faraway places (Mohamed et al. 2021).

34.4.3 Robotics in Agricultural Work

Robots are intelligent machine formed by computers, electronics, and mechanical engineering that mimics human work patterns. Crop harvesting and post-harvest procedures are among the applications of agricultural robotics. Robotic technology not only eliminates agricultural labour but also prevents farmers from working in severe situations. Furthermore, agricultural production involves living products (fruit, vegetables, grains, and flowers) that are very sensitive to environmental and physical factors (Jyoti et al. 2020). Produce during and after harvest needs delicate, precise, and frequently complex care to preserve quality across long distances and time. This trait makes machine or automation replacement of human competence difficult. The majority of labour-intensive jobs in fruit, vegetable, and flower cultivation are still done by hand. Manual labour accounts for up to 40% of overall field operations costs (Bechar and Vigneault 2016). Most agricultural activities occur in unstructured settings characterized by frequent changes in time and place. The topography, vegetation, scenery, visibility, light, and other atmospheric variables in the agricultural field are dynamic, ill-defined, and unexpected. This means that the notion of using robots in agriculture must be compatible with current technology and economically viable. In many agricultural unit operations, robotic technology has been used to mimic or emulate conventional agricultural processes, although no commercial robots for complicated agricultural fields are available (Jyoti et al. 2020).

Sensors, end effectors, control systems, manipulators, and power supply comprise a robotic system. End effectors are robotic parts that connect to their arm or appendages and are used to handle, grab, or grasp items. Manipulators are finite non-rigid elements called links. Robotic joints include revolute, cylindrical, planar, spherical, screw, and prismatic joints. The robot work volume is the three-dimensional space where it can sweep its wrist to maximum and lowest reach. Sensors collect data from the environment and turn it into usable form. Sensors have static and dynamic properties. Tactical and wheeled sensors are utilized in robots. Tactical sensors sense physical contact, whereas wheeled sensors monitor motor position or speed. When developing a robotic system, one must consider the influence of power sources on the mechanism, packaging, weight, and size of the system. Generators, hybrids, batteries, solar cells, and fuel cells are widely utilized in robotics. The control system regulates the behaviour of other subsystems and requires data and information about their present and future phases.

Agricultural autonomous robots are designed to perform and take decisions even in an unstructured and changing environment. Creating an autonomous robot is difficult because of the need for real-time sensor control and modelling solution. Agriculture's autonomous robot is divided into subsystems that conduct certain tasks. In addition, these subsystems and gadgets provide direction on handling single or simultaneous multiple unexpected occurrences and also provide autonomy in the system. The system's main purpose is to plant and seed, while the second task is to move about and interact with humans and other robots. The main component of the robot is meant to mimic conventional agricultural unit activities using end effectors and manipulators. The secondary component interacts with the earth to drive the vehicle in the anticipated direction at the optimum speed (Bechar and Vigneault 2016; Jyoti et al. 2020). Autonomous robots that can pick large quantities of crops quicker than human labourers are being employed in agriculture. Examples: Robots (Harvest CROO Robotics 2021) substitutes 30 human employees for harvesting and packaging of strawberries with the capacity of 8 acres/day. In vineyards, photos were captured using drones to assess crop health (Muniasamy 2020). Nishiura et al. (2013) designed a robot with better soft handling and alignment to raise and graft seedlings with 95% success rates. An automated real-time kinematic positioning guided weed-control system was utilized. An intelligent hoe employs visual systems to recognize rows of crops and manoeuvre itself between them (Slaughter et al. 2008). EcoRobotix is a completely autonomous robot that kills weeds in the agricultural field. The system sprayed at the appropriate area with little harm. The robot's environment variables may be changed (EcoRobotix 2019). Utstumo et al. (2018) developed a system to adapt for changes in cultivation techniques, crop rows, track width, and crop height. Robotics decreased manual labour by 50–100 per cent in naturally produced sugar beets and vegetables and pesticide consumption by 75–100 per cent in high value crops. Robotic weeding was created for maize by Zhao et al. (2016). Various researchers have explored the semiautomatic teleportation of an agricultural robotic system for tomato picking, weed control, and spraying to increase performance (Bakker et al. 2010). Robots are automatic systems that conduct very complicated and unstructured tasks in agriculture. Various subsystems are required to complete the job. Unstructured agricultural robotic systems must be designed to maximize productivity and quality of labour. In recent decades, significant improvement has been made.

34.4.4 Use of Internet of Things in Agricultural Implements

IoT-based smart farming allows farmers to use smart technology in their fields to decrease energy waste and increase output and productivity. It gives farmers more control and makes conventional agricultural practices outdated. In 2015, Business Insider predicted 30 million IoT devices used in agriculture, and by 2050, IoT-connected farm-generated data will be 4.1 million/day. IoTs help farmers to offer real-time data for improved crop production decisions. A drone used for pesticide spraying saves labour costs in tough places, while soil monitoring increases production. Modern IoT-based irrigation, automation, crop development monitoring and management, pest control, and pest population control are all examples of smart farming. This farming collects, monitors, and controls agricultural data. Machine-generated data from remote sensing, satellites, or unmanned aerial vehicles. Sensors and other smart equipment help the farm measure and record many operations. The data is currently utilized as IoTs and is suitable for computer processing. A traceability system increases consumer trust in agricultural goods. Eco-data may be collected using smart farming's integrated sensors. Smart dairy technologies include automated feeding, management, milking, and daily health maintenance. Precision farming uses IoT to track soil plots, seedlings, and water conditions. Images, sounds, graphical patterns, and wavelengths may be employed in IoT and advanced technical analysis. The applications of IoT in agriculture are represented in Fig. 34.6. Subahi and Bouazza (2020) developed an intelligent system based on IoT for greenhouse temperature management for the preservation of food quality and also for energy saving. The developed system maintains the optimum temperature around which the system regulates. Sagheer et al. (2021) connected sensors, actuators, and other equipment and put them within the greenhouse to test the platform on cucumbers grown on a soilless medium. They tested this technology in a greenhouse used for commercial production to determine the effect on crop output such as yield and quality. They also revealed that the system boosts plant growth and output while saving money on water and electricity. Agriculture equipment manufacturers (CLAAS, John Deere, Mahindra & Mahindra, YANMAR, etc.) have integrated IoTs in their tractors. For example, YANMAR began developing a robot tractor in 2011 and won the Robot Award in 2016.

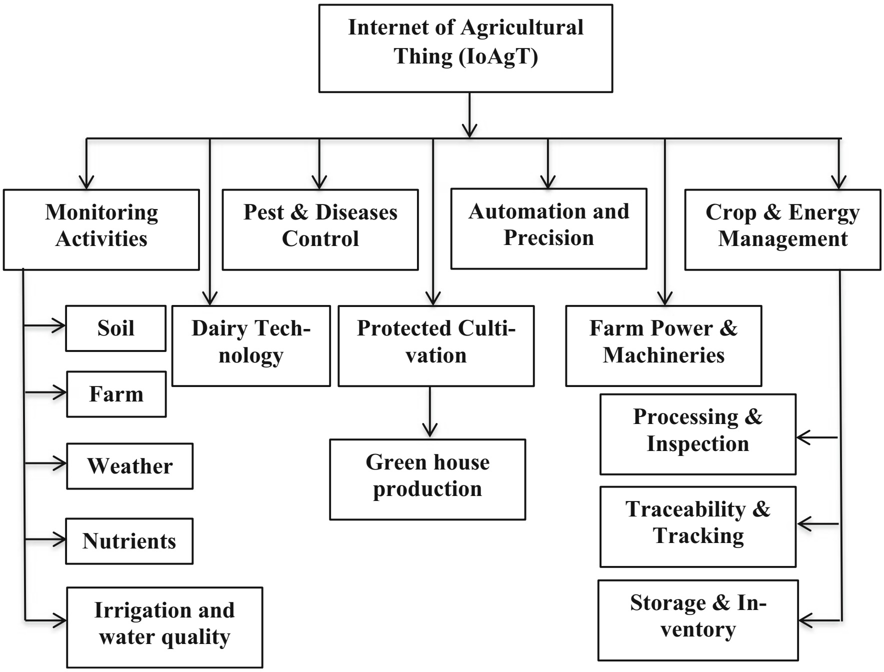

Fig. 34.6 Applications of IoT in agriculture. Reprint with permission from Santra et al. (2021)

Automated rice transplanters, smart combine harvesters with yield monitoring systems, and smart spraying will transform the way agriculture is done in the future. The Precision Hawk's UAV sensors might offer wind speed and pressure data. Subsoiling may improve soil physiochemical characteristics, soil permeability, crop root system conditions, and yield. Ploughing and sowing need IoT-based agricultural machines. There would be a better technique to obtain perfect seed spacing using mechatronics used in precision planter and seeder. The IoT application in mechatronics will be future agricultural sowing technologies. Australia-AgBot, Europe-CROPS, Finland-Demeter, India-Agribots, Michigan-Hortibot, USA-ISAAC2, and many more nations created prototypes. IoT may be used to handle agricultural supply chain information including crop production, procurement, transportation, storage, and sale. The system delivers agricultural items like fertilizers, insecticides, and seeds to farmers at the correct time and the right price. Concerned about the environment, IoT uses nutrients, water, and insecticides efficiently. Overall, IoT-based machines replace human labour in agricultural monitoring and production (Kushwaha 2019).

Farming also includes livestock monitoring. Traditionally, cattle were fenced in and monitored manually, while modern technology allows for automated tracking and monitoring of livestock. Cattle tracking use GPS with navigation satellites. The application of UAVs makes real-time livestock monitoring simple and economical. Virtual fences may also be created using wireless sensor networks, radio-frequency identification (RFID), and low-power wide-area networks (LPWAN) (Ilyas and Ahmad 2020).

Several researchers already suggested IoT-based geo-fencing and smart agricultural systems. Germani et al. (2019) proposed a long-range LPWAN technology to gather and analyse metrics relevant to cattle health and the environment. An application server processes the data and presents this to the user for further analysis. Simulation results indicated that the suggested architecture covers 7 km^2 hilly terrains successfully.

34.4.5 Artificial Intelligence

Artificial intelligence (AI) represents human intelligence simulations with machines that are often programmed to think like humans and mimic their behaviour. It also includes computer development or mobile-based intelligent software which is compatible with agricultural user behaviour. In the days to come, most of the agricultural operations will be very much related to AI. This will lead to the development of self-learning algorithms and will help in automation of agricultural practices. Major farm operations including seed bed preparation, sowing/transplanting, weeding, spraying, harvesting, threshing, and transportation will be performed via AI-based applications. Currently, this technology is at an emerging stage, and with time and capital investment, all of the above form operations will be automated, which will increase input utilization efficiency and reduce production costs. Likewise, the Internet of Things (IoT) in agriculture is evolving as new technology includes robotics, unmanned agricultural vehicles (UAV), GPS and remote sensing (RS)-based technologies, and computer-based imaging systems. These technologies comprise different sensors which are readily available in the local market at a lower cost. These sensors will help in the identification and estimation of the soil health conditions, status of ground water levels, NDVI, chlorophyll Index, and crop stress in real time. In India, there are around more than three hundred start-ups in the IoT space, out of which nearly 40–50 are focusing on smart agriculture technology. The adoption and development of IoT-based agricultural devices in India will be a boom for the agricultural industry.

The use of IoT in farm machinery can increase precision and accuracy in farm operations, and ultimately it initiatives smart agriculture with enormous potential with improved technological solutions to the food supply chains and agriculture farming practices. There is also a signal towards better water utilization practices such as sprinkler and drip irrigation systems. In order to reduce the deficit of agricultural production, smart technology needs to be developed in the future; it is very important to keep in mind the small and marginal farmers. At the same time, private and custom hiring organizations can provide support for smart agricultural mechanization. A tractor is one of the major prime movers in agricultural farm operations which requires a skilled person to operate it efficiently. Farming activities are greatly affected by the weather and environment during working hours and nonworking hours. Currently, state-of-the-art technology is equipped with attractive features such as auto-steer, auto-headland turns, auto-implement elevator, skip passing, and safety features such as geo-fence lock and remote engine begin to shut down. The GPS-based auto steer and auto head land turned low a tractor to travel precisely along as straight line and for continuous operation, it can orient itself along with adjacent rows without any giving input steering, respectively. However, an auto implement lift can automatically lift a machine or implement from the base. Tractors modernization through artificial intelligence will lead to higher food production, productivity, higher incomes, and lower health risks for farmers who can meet the growing needs of the growing population.

34.5 Conclusions

Day by day, agriculture is getting popularized. Manufacture and distribution of innovative technologies in agricultural farm machines, implements, tools, machines, etc. for every region of the country including arid zone are now fast growing to increase farmer profitability and crop productivity, to help farmers engaged in agriculture and allied sectors, to acquire the means to modernize their farming operations, to provide the necessary custom hiring services for these purposes, to provide technical guidance to farmers and persons belonging to agro-industries, and to enable efficient management of input resources in agriculture. Smart agricultural mechanization is a boon to the agricultural development paradigm that has been widely encouraged to transform agriculture in all countries. The following conclusion can be drawn from reviewing agricultural mechanization.

- Adoption of smart agricultural equipment like zero till drill, no-till drill, combined tillage practice, laser land leveller, and controlled traffic system for seedbed preparation can reduce greenhouse gases, remove carbon from the atmosphere and store it in the soil, and reduce soil disturbance and agricultural inputs.
- Agricultural mechanization in sowing or transplanting is very much required to achieve the desired yield of crops in arid region. Due to labour crisis and human limitations, it is not possible to sow any particular crop in time by manual method. Agricultural mechanization brings timeliness, accuracy and cost-effectiveness in farm operations. It's also enhance conservation of resources (soil and water) and applied input efficiency.
- There is tremendous research scope on mechanical weeder, inter- and intra-row weeder, and implementing robotic weed control systems for various field crops of arid regions.
- Using real-time clocks, humidity sensors, temperature sensors, mechanized micro-sprinklers, and drip and automated irrigation systems helps reduce water waste, as market demand in our countries is emerging.
- Smart agricultural technologies allow farmers to ensure crop input efficiency by optimum utilization of water or chemical fertilizers which helps to increase in productivity and better yield in terms of product quality.

- Mechanized harvesting and threshing operation needs majorly due to timeliness these operations in order to reduce losses occurring by rodents or climatic changes like rain in the arid region.
- Finally, there is a need to prioritize agricultural mechanization in the arid region and create awareness among the farmers about the techniques of agricultural machinery. A lot of agricultural machinery is being developed, and government subsidy is being given to counter the high cost of agricultural machinery.

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