CHANGES OF RICE PRODUCTION SYSTEM IN CENTRAL DRY ZONE OF MYANMAR: A CASE STUDY IN MEIKTILA TOWNSHIP

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CHANGES OF RICE PRODUCTION SYSTEM IN CENTRAL DRY ZONE OF MYANMAR: A CASE STUDY IN MEIKTILA TOWNSHIP

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A thesis submitted to the post-graduate committee of the Yezin Agricultural University as a partial fulfillment of the requirements for the degree of Master of Agricultural Science (Agronomy)

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The thesis attached hereto, entitled **"Changes of Rice Production System in Central Dry Zone of Myanmar: A Case Study in Meiktila Township"** was prepared under the direction of the candidate's supervisory committee and has been approved by all members of that committee and board of examiners as a partial fulfillment of the requirements for **the degree of Master of Agricultural Science (Agronomy**).

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DECLARATION OF ORGINALITY

This thesis represents the original work of the author, except where otherwise stated. It has not been submitted previously for a degree at any other University.

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DEDICATED TO MY BELOVED PARENTS,

U MG MG KHIN AND DAW KHIN YI SAW

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ABSTRACT

The Central Dry Zone comprises about 22% of total rice production in Myanmar. Drought is the most severe hazard amplified by climate change, since it causes scarcity of food and drinking water for human and cattle, changing cropping patterns, declining crop yield and losses in their livelihoods. This study aimed to investigate the changes of rice production system between 2000 and 2018 in Meiktila Township. This study was conducted in four village tracts of Meiktila Township during June-September, 2018. A total of 160 respondents were selected by using purposive random sampling method. The primary data were demographic factors and changes of cultural practices in rice production and secondary data were 10 years trends of the climate data, rice sown area and rice production. According to water uncertainty, total farm size and rice growing areas of respondents were decreased between 2000 and 2018 and number of small holders was increased in the study area. But some respondents changed to practice double crop (rice-rice) from mono rice crop due to availability of irrigation water in some areas starting from 2015. Most of the respondents changed to practice intermittent irrigation from permanent flooding in 2018. Almost all of the respondents usually practiced transplanting method between 2000 and 2018. In 2000, the respondents used animal drawn implements for land preparation, manual harvesting and threshing in wet season. In 2018, traditional and manual operations were changed to mechanization because of availability, time saving and efficiency of farm machines. The respondents used more hired labours than family labours in rice establishment, weeding and harvesting. Non-farm incomes of respondents were increased in 2000 and 2018. According to extension activities, changing of traditional varieties to certified improved varieties and more use of N, P, K fertilizers (71.7 N kg per ha, 5.6 P kg per ha, 8.3 K kg per ha) were found in 2018. Under these circumstances, Rice yield was increased to 3.3 ton per ha in 2018 from 2.3.ton per ha (2000) in the study area. Similar trend was also observed in dry season rice. In the study area, water was the most limiting factor for improvement in rice productivity and the other factor is fertilizer application; Nowadays, cultural practices of respondents were changed to new practices however nearly half of the respondents did not change. Therefore, based on this study, policy makers and all stakeholders involved in rice value chain should be taken into consideration of some recommendations for improving rice production systems in central dry zone.

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CHAPTER I
INTRODUCTION

Myanmar is an agricultural country well-endowed with land, a generally favourable climate and plentiful water resources for agricultural production. The agriculture sector plays an extremely important role in the economy and is the main source of income for about 60% of the working population. Myanmar's gross domestic product grew at 6.8% in 2017 and is projected to grow at 6.8% in 2018 and 7.2% in 2019 (Asia Development Bank [ADB], 2018). However, 32.1% of the population remains poor (World Bank, 2017a) and the poverty incidence in the Central Dry Zone (CDZ) is high (43%) (Japan International Cooperation Agency [JICA], 2010). The Central Dry Zone (CDZ) has 15.4 million inhabitants, most of whom (76%) live in rural areas; 58% of CDZ households depend on crops for their livelihoods. Tackling rural poverty is critical to ensure sustainable development in the CDZ. In 2016 agriculture accounted for 30% of gross domestic product, 60% of employment, 29% of value addition, and 23% of exports (including $1.1 billion in pulses alone) (The European Chamber of Commerce in Myanmar, 2017). Crop production accounts for 72% of farm outputs. As a percentage of national production, the CDZ produces 25% of rice, 48% of pulses, and 89% of sesame.

Despite good resource endowments, agricultural production and productivity remain low, primarily due to (i) poor infrastructure, (ii) low-quality inputs, (iii) weak institutional capacity, (iv) limited access to finance, and (v) high vulnerability to climate risks. A farmer in Myanmar earns only about $1.80–$2.50 per day compared to $10–$16.50 in Thailand and $7.80 in the Philippines (World Bank, 2017a). Most farms are small, subsistence-level holdings with low productivity (average paddy yield in Myanmar is 2.7 tons per hectare versus a potential yield of 6.8 tons per hectare).

Low usage and quality of certified seed and agro-chemicals, limited irrigation, and poor quality and safety of farm products also contribute to low sector performance. Less than 5% of rice farmers in the CDZ use certified seed, while pulse and oilseed farmers use almost none. Private seed providers have been unable to produce enough to meet demand because of the poor business environment. Only 15% of crop area is irrigated, and more than 50% of the rural population lacks access to all-season roads, hindering farm-to-market connectivity. Credit (which is often unavailable) is of short tenure, and given only to land owners. Increased migration to urban areas and neighboring countries is worsening labours shortages. Farm mechanization is limited. Inefficient post-harvest

operations such as drying are leading to reduced quality, and poor returns to farmers and processors. Most exported crops are unprocessed and sold to lower-value markets. Private sector investment in agribusiness is limited because of the poor enabling policy environment related to land use and administration (Global Agriculture and Food Security Program, 2016). In Doing Business 2018, the World Bank ranks Myanmar 171st out of 190 economies (World Bank, 2017b). During 1998–2017, only 23 agricultural enterprises attracted foreign direct investment, amounting to $380 million or 0.51% of total foreign direct investment (World Bank, 2017a).

Myanmar has one of the highest rankings in the 2017 global climate risk index (Eckstein, Künzel & Schäfer, 2017). While total precipitation has changed little from 1990, the rainy season has shortened due to late onset and early withdrawal of the southwest monsoon, causing intense rainfall and flooding. Increasing temperatures, shallow soils, a long dry season, the increasing frequency of severe droughts, and poor crop husbandry are adding substantial risk to agriculture. Climate change projections to 2050 suggest Myanmar will experience longer dry spells and periods of heavy rains. Policy reforms undertaken since 2011 have enhanced the potential for growth in the agricultural sector (Raitzer, Wong & Samson, 2015). Investing in infrastructure, capacity and the enabling policy environment can unlock agribusiness's potential. Improved access to certified seeds, water, and land and finance, and the use of quality agro-chemicals and climate- resilient varieties can lift crop productivity to regional norms and address climate change. Investments in resilient farm roads can increase market connectivity, while quality and safety testing of infrastructure can boost export potential. The potential for exports can be enhanced by strengthening the capacity of smallholders in good agricultural practices (GAPs) and climate smart agriculture (CSA), and of agribusinesses in good manufacturing practices and safety standards. Support for formulating climate- and investor-friendly agribusiness policies, coupled with enhanced land administration and credit services at the township level, can spur faster, better, and stronger agribusiness growth.

The Ministry of Agriculture, Livestock and Irrigation (MOALI) has developed the Agriculture Development Strategy (ADS), 2018–2023 (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2018), the agriculture sector second five-year plan, a rice sector development strategy, and a CSA strategy (MOALI, 2016b) The ADS aims to improve food security and agricultural competitiveness. The five-year sector plan aims to improve irrigation, crop production, agro-industry, markets, and research. The CSA

strategy aims to achieve food and nutrition security and climate resiliency, with a globally competitive agriculture sector by 2030.

Global climate change is well evident not only in the delta affected by Cyclone Nargis, but also in the central dry zone. In some areas, the onset of monsoon was later than usual and precipitation pattern has also changed causing extreme weather phenomenon. In central dry zone, Meiktila Plain, of which agricultural productions totally rely on water supply from small dams and tank irrigation, for successful harvest, the impact of climate change is quite severe. Although small dams and tanks could provide enough irrigation water for crop establishment, irrigation for the whole cropping season is not assured (Kyi, 2016).

The dominant features of the Dry Zone regions include erratic rainfall, sandy soils with low fertility and low water-holding capacity, and high temperatures. Since the region chronically receives a low rainfall compared to the other parts of Myanmar, local people meet unstable livelihoods with little prospect of increasing agricultural production. It is said that most of the small holders have employed practices designed to optimize productivity in the long term rather than to maximize it in the short term (Glissman, Gracia & Amador, 1981). In order to achieve the optimized sustainable agricultural production, it is indispensable to evaluate the local agricultural resources and past and present farming systems. Therefore, survey and exploration had been made to investigate the changes of rice production system between 2000 and 2018 in Meiktila Township.

CHAPTER II
LITERATURE REVIEW

2.1 Rice Ecosystems in Myanmar

The major rice-producing regions of Myanmar are in the delta. Ayeyarwaddy, Bago and Yangon regions make up almost half of the country's harvested rice area (Ministry of Agriculture and Irrigation [MOAI], 2011). Myanmar's major rice ecosystems include rainfed lowland rice, irrigated lowland rice, deepwater rice and upland rice. Rice is grown in Myanmar during the monsoon (June to November) and summer (December to May) seasons. There are two dominant rice production systems: rainfed lowland and irrigated lowland. During the monsoon season, Myanmar's rainfall in the delta and coastal region is sufficient for growing rice without supplemental irrigation from dams, river and stream diversions or groundwater. Where available, irrigation coupled with drainage structures, improves stability of production and reduces the risks of flooding and stagnant water. Large areas of the delta are subject to flooding ranging in duration from a few days to 2 or 3 months, presenting significant risks to farmers. Some areas, though declining in importance, are suitable for deepwater rice, a low yielding rice type that elongates to stay above the rising water. Other varieties, including a new variety carrying the Sub1 gene (Bailey-Serres, Fukao, Ronald, Ismail, Heuer & Mackill, 2010), demonstrate adaptation to periods of total submergence, a potentially valuable trait as more frequent and prolonged submergence events may be a consequence of climate change. Without the benefit of submergence tolerance, excessive flooding severely limits the scope for using improved high yielding varieties and crop management. Another relatively minor system involves transplanting of rice as floodwater recedes after the monsoon season, with subsequent irrigation from the receding water (Denning, Baroang & Sandar, 2013).

In the dry zone, annual rainfall of 750-1,000 mm is generally inadequate to produce a rainfed rice crop except in low lying areas with a high water table. Rice grown in the dry zone can be productive when grown under irrigated conditions because of the increased hours of sunshine, especially during the summer season. Upland rice is grown in the hilly areas under a shifting cultivation known as taungya. Upland rice is direct seeded into moist soil with the first rains. As little as 200,000 ha of upland rice is planted in Myanmar, more than half of which is grown in Shan State. Fujisaka (1992) described upland rice growing in rotation with potato and peanut in upland areas. Farmers reported

using traditional varieties though some used fertilizer. As in most of Asia, upland rice has reduced in importance as productivity in lowland areas has increased and market access to the uplands has improved. These developments favor the adoption of higher value agricultural enterprises.

2.2 Application of Good Agricultural Practices in Rice Production

Rice has been cultivated in Myanmar since prehistoric times. Before World War II, Myanmar became the largest rice exporter in the world. Rice area and production declined during the post-war era and has since failed to reach the levels achieved during the pre-war period. Rice production is increasing mainly due to area expansion rather than yield increase per unit area. As an important crop for home consumption and export, Myanmar designated rice as a national crop with a target yield of 5.2 tons per ha (MOAI, 2013a). In the phase of climate change, the country has been experiencing the negative impacts of floods, droughts, and high temperature, among others. The rice sown area, harvested area, and yields decline almost every year. MOAI introduced the application of GAP as a policy in 2008–2009. To meet the target yield and production, suitable areas were selected from various states and regions. These areas were assigned to apply GAP in rice cultivation yearly, and the sown areas were extended year after year. In 2010–2011, GAP was applied to about 3 percent of the total sown areas of monsoon rice. In 2014–2015, 41.69 percent (2,134,389 ha) of the total sown area of monsoon rice (5,120,220 ha) were cultivated using GAP. The application of GAP is more feasible in areas where irrigation and drainage are operated easily. DOA extension workers are currently striving to promote the farmers' adoption of GAP in monsoon rice and summer rice production (Department of Agriculture [DOA], 2014). The implementation of GAP is successfully in progress through the collaboration of DAR, YAU, AED of DOA, and model farmers. In 2011, MOAI set 14 guidelines for GAP in rice cultivation. Among the guidelines, farmers mainly focus on the alternate wetting and drying technique for water management. They choose lands that are more suitable for proper water management of irrigation and drainage. The guidelines for GAP are also in line with SRI, which includes the following characteristics, among others;

- age of seedlings; young seedlings are transplanted at 8–12 days
- number of seedlings; 1-2 seedlings per hill are transplanted to a shallow depth of 1–2 centimeters (cm)
- spacing of plants; hills have a wider spacing of 20–30 cm

- water management; non-flooded aerobic soil conditions with intermittent irrigation
- weed and pest control; manual weeders can remove weeds and aerate the topsoil simultaneously; IPM practices are encouraged
- soil fertilization; organic matter is preferred to the extent feasible, but may be complemented with synthetic fertilizers (Lampayan, Rejesus, Singleton & Bouman, 2015)

Among the GAP guidelines, farmers mainly focus on the Alternate Wetting and Drying (AWD) technique for water management, choosing lands that are more suitable for proper water management of irrigation and drainage. The traditional practice of growing rice in continuously flooded fields consumes a disproportional amount of water compared to other crops. Appropriate use of AWD offers considerable savings in water use during the rice-growing season without reducing crop yield (Lampayan et al., 2015).

2.3 Introducing of HYV Variety

To improve the country's rice industry, The International Rice Research Institute (IRRI) launched a high-yielding variety (HYV) pilot project to support the distribution of technology and inputs, from 1977 to 1978. MOAI launched a special high yielding paddy program in Shwebo (Central Myanmar) and Teikkyi (Lower Myanmar) Townships to support the distribution of technology and inputs, such as seeds, chemical fertilizers, and irrigation, as well as the close supervision of agricultural extension staff. This program introduced rice HYVs such as IR5 and IR8. The yields doubled with the application of improved techniques, such as the use of chemical fertilizers and pesticides, as well as proper water management (MOAI, 2013b). The summer rice program, which was introduced in 1992, used short-duration HYVs and increased rice yield. The government of Myanmar strongly supported summer rice production, which was intensified yearly. Rice has been designated as a national crop and a priority crop for area expansion and yield increase. New irrigation dams, weirs, and reservoirs were established; existing irrigation facilities were improved; and groundwater was explored to further rice production.

In the rice value chain, the main actors are farmers, traders, collectors, millers, and the development of new varieties that are high yielding and tolerant to unfavorable climate. DAR, through DOA, is primarily responsible for the production and distribution of rice seeds. The dealers sell other inputs such as chemical fertilizers and pesticides. For

increased production, the farmers need inputs such as seeds and agro-chemicals. Financial support mostly comes from the millers and the money lenders (Lampayan et al., 2015).

2.4 Opportunities for Improving Agricultural Productivity

Nine intervention areas were identified in the rice production cycle where improvements in productivity and profitability can be achieved. Each of these intervention areas has relevance to both the rainfed lowland and irrigated rice systems.

1. Seed selection
2. Land preparation
3. Crop establishment
4. Water management
5. Soil fertility management
6. Pest management
7. Harvesting and threshing
8. Drying and storage
9. Crop rotation

Seed Selection: There are two components to seed selection: choice of variety and quality of seed. The choice of variety is made by farmers based on a combination of factors that include: (1) adaptation to the growing environment, (2) eating/cooking preferences of the consumers, (3) market preference/price, and (4) cost of seed. Modern rice varieties (also known as HYVs) are variously reported to be used for 70-80% of the monsoon crop and for virtually all the summer crop. HYVs are widely grown in the summer season because of their early maturity and the absence of flooding risk at that time of year. Nationwide, HYV adoption has been reported as 61%, with highest levels of adoption in the dry zone (Fang et al., 2009). Through cooperation with IRRI's scientists, Myanmar researchers could use "gene pyramiding" to develop "climate smart" varieties with multiple adaptation traits that are ready for farm use within 3-4 years. Past experience suggests that well adapted varieties will spread rapidly through Government production of seed, strategic field demonstrations, and seed exchange among farmers. The MOAI has actively promoted the use of hybrid rice in recent years in cooperation with Chinese technicians. The MOAI reported hybrid seed production during the 2011 summer season on over 300 ha using "Pa-le-thwe" variety. Most of Myanmar's rice farmers use their own seed from year to year. There is a national seed certification system in Myanmar. The Government advocates the use of high-yielding certified seeds. However,

the private seed sector is poorly developed. A well-managed public sector seed system is essential for non-hybrid rice varieties. Once well adapted named varieties are made available to farmers, the seed can be readily multiplied and distributed through informal farmer-to-farmer mechanisms. A nation-wide varietal evaluation system must be linked to seed production and distribution programs.

Land preparation: Lowland rice fields in Myanmar were traditionally plowed with cattle or water buffalo, the latter being more common in lower flood-prone landscape positions. Two wheel tractors, most imported from China, are increasing in importance. For most rice-growing areas, two-wheel tractors currently appear to be the best solution for reducing the land preparation time and enabling a short-turnaround between crops. Complementing the use of four-wheel tractors, attempts have been made by the MOAI and IRRI to introduce laser leveling as a means of improving land preparation and crop establishment. Laser leveling was introduced by IRRI in 2006 for demonstration purposes. It has not been widely used to date. The high cost of equipment, the need for skilled operators, and the irregularity of field shapes all constrain adoption. However, there is scope for laser leveling as part of a broader initiative to consolidate rice fields for operational efficiency. With relatively large fields and reported labours shortages in rural areas, it is likely that mechanization of tillage will grow rapidly in Myanmar (Denning et al., 2013).

Crop establishment: In Myanmar, rice is usually established through transplanting or direct wet seeding. Transplanting is the most common method for monsoon crop establishment, giving the rice plant a competitive advantage over weeds. For the transplanting method, rice seedlings grown in a nursery are pulled and transplanted into puddled and leveled fields 15 to 70 days after seeding. This operation can be done manually or using a machine. Manual transplanting is well suited to situations where the land is uneven, the water level is variable, and labours costs are low. In Myanmar, wet seeding is more common for the summer rice crop. This is because of the lower likelihood of submergence and related mortality of young seedlings. The drum seeder was widely distributed in Myanmar through Livelihoods and Food Security Trust Fund (LIFT) and implementing partners with mixed results (Barca & Riemenschneider, 2012). While having the potential to save seed and reduce labours costs, adoption rates remain low. Farmers reported that drum seeders consumed more time than direct broadcasting, and required a greater investment in hand weeding.

Water management: Myanmar has extensive water resources available for irrigated agriculture, including for rice farming. Surface water from the Ayeyarwaddy and Sittoung River Basins has been developed for rice irrigation over the past century (Naing, 2005). In most settings in Myanmar and elsewhere in South and Southeast Asia, farmers seek to maximize water flow to their fields to reduce the yield-reducing effects of water deficit. In irrigated rice, farmers are concerned about their access to adequate water from canals. Competition for water is common during the dry season, especially where there is limited regulation and an absence of cooperative water management. In low lying fields, there are risks of submergence and stagnant water, both of which can sharply reduce yields. Salt water intrusion affects rice in the delta, and is more serious in the summer crop season. Around 3% of the country's rice is affected by salinity. Alternate Wetting and Drying (AWD) is a water-saving technology that irrigated rice farmers can apply to reduce their water use. With AWD, the field is alternately flooded and non-flooded. The number of days of non-flooded soil in AWD between irrigations can vary from 1 day to more than 10 days. The moisture content of fields is determined through field water tubes. Based on the level of water in these tubes, farmers can determine when to irrigate. This method works only where farmers have direct access to and control of water delivery, e.g., through groundwater. The method is widely adopted in China. While improving water use efficiency, yield reductions are common (Bouman, 2007). Overall, AWD may find a useful niche in rice growing areas with reliable pump access to groundwater and surface water bodies. Overall, the best option for water management is to expand access to irrigation, coupled with investments in drainage. The Shwebo Irrigation Scheme, drawing on water from the Thapanzeik Dam and Kabo Weir, appear to have the necessary infrastructure to support productive irrigated agriculture. The team was informed of plans to extend the command area of the Scheme through a new canal on the western side of the Mu River. Improvements in water use efficiency would likely be achieved through: (1) farmer organization through water user groups, (2) improved extension support, (3) infrastructure to support storage, processing and marketing, (4) improved rice varieties and associated agronomic management practices, and (5) crop diversification to high value (non-rice) crops during the summer season (Denning et al., 2013).

Soil fertility management: Overall the rice soils of Myanmar appear relatively fertile. Alluvial and swampy soils dominate in the delta, while vertisols are more important in the irrigated rice lands of the dry zone. Information on current fertilizer use by farmers is

limited. Livelihoods and Food Security Trust Fund [LIFT] (2012a) reported that, during the monsoon season, 63% of rice farmers interviewed in the delta/coastal zone and 76% in the dry zone applied inorganic fertilizer. Research undertaken by IRRI has demonstrated good responses to fertilizer during the summer season (International Plant Nutrition Institute [IPNI], 2005). During the 2005-6 summer season, site-specific nutrient management (SSNM) was evaluated and demonstrated in collaboration with the Myanmar Agriculture Service (MAS) in 72 on-farm trials in six townships (Kyaiklatt, Myaung Mya, Letpandan, Pyay, Shwebo, and Taikkyi) in four of the major rice growing divisions in Myanmar. Low fertilizer use on rice and modest yield levels suggest moderate to high responses to increased fertilizer use in Myanmar. SSNM improves nutrient use efficiency and matches fertilizer use and crop needs based on a target yield. SSNM is a sound approach and deserves attention by extension services in Myanmar.

Pest management: There are a large number of insects that feed on the rice crop. Morris and Waterhouse (2001) documented 29 species of insects and crabs that feed on rice in Myanmar. Naing, Kingsbury, Buerkert & Finckh (2008) reported a low incidence of pests and diseases in the main rice growing areas of upper and lower Myanmar. Recent research by Aung, Aung, Escalada & Heong (2012) reported farmers using a narrow range of insecticides in Myanmar. Most commonly used pesticides were organophosphates and organochlorines, particularly dimethoate, phenthoate and endosulfan, all of which are banned or under restricted use in most countries. Without regulation and sound extension advice, Myanmar's rice farmers are likely to experience the disastrous effects of crop damage caused by the brown planthopper (BPH), as experienced in Thailand, Indonesia and China over the past three decades. BPH resurgence is associated with the killing of natural BPH enemies through inappropriate use of pesticides. The concept of "ecological engineering" was introduced to Myanmar through a training workshop in 2011. These approaches point to pesticide use as a weapon of last resort. Indeed, Dr. K.L. Heong, one of the pioneers of integrated pest management (IPM) and ecological engineering, is adamant that Myanmar farmers are much better off not using any insecticides at all. Aung et al., (2012) stated that even with formal registration of pesticides, there needs to be licensing and advertizing restrictions, coupled with training and awareness programs, in order to avoid overuse. Naing et al., (2008) also reported on weed control practices in rice. Hand-weeding was most commonly observed. Overall, farmers in all regions expressed only very basic knowledge about chemical weed control methods.

Harvesting and threshing: Rice is generally harvested manually using family and/or hired labours, the balance of which depends on farm size. After harvesting, farmers usually stack their stalks un-threshed on the paddy field bunds. This practice is undertaken to focus labours on land preparation to enable a quick turnaround to either a second rice crop or a post-rice pulse crop such as green gram. Early crop establishment is associated with higher yield, and pulses attract a much higher price than rice. The downsides of stacking on bunds are losses through rat damage and shattering, and deterioration in grain quality, especially if there are rain showers. Threshing is done traditionally through trampling by cattle. However, mechanical threshing is increasing in importance. This combination of hand harvesting and mechanical threshing is the intermediate step to combine harvesting in response to higher wage rates. However, it is reasonable to anticipate widespread use of combine harvesters in Myanmar over the coming 5-10 years. Mechanized harvesting and threshing will likely reduce the losses associated with an extended period of field stacking (Denning et al., 2013).

Drying and storage: Farmers normally sun-dry their grain on any available space, including on roads. The latter practice leads to uneven grain drying which, in turn, results in a higher proportion of broken grains and lower quality of the final product. Stones and other impurities further reduce quality. IRRI introduced a modified flat-bed dryer using a rice husk furnace to Myanmar in 2007. The technology originated at IRRI, but was modified in Vietnam, where there are now more 7,000 dryers in the Mekong Delta. There are now around 120 dryers of the original Vietnamese design and another estimated 200 copies. Members of the mission observed rice-hull fueled driers in action in Shwebo. The fans of these driers are mostly powered by diesel generators which are more cost-effective and reliable than using grid-sourced electricity. These driers appear relatively easy to construct, operate and maintain, and are already being manufactured in Myanmar by manufacturers trained in Vietnam with support from IRRI. Farmers store unhulled rice for both grain and seed. Rice for consumption and later sale is normally stored unhulled rather than as milled rice, as the husk provides some protection against insects and helps prevent quality deterioration. A new system of hermetic storage developed by IRRI has shown promise. At the farm level, unhulled rice can be stored in sealed plastic bags. This method controls the moisture content of the grain. Respiration by the grain and insects inside the storage container consumes oxygen and produces carbon dioxide. Oxygen levels are reduced from 21% to less than 10% within a short period of time. Below 5%

oxygen, insects are killed and the viability of seed retained. Hermetic storage does not work with milled rice because of the lack of biological activity. A national distributor for hermetic storage systems was recently appointed so the systems should soon be available in Myanmar (Denning et al., 2013).

Crop rotation: In some areas during the 1990s, the Government promoted double cropping of rice during the monsoon season as a way of boosting production. However, farmers found it difficult to harvest and dry the first crop at that point in the monsoon season (usually in September/October) and this practice has been largely discontinued. For more than 20 years, farmers have been strongly encouraged by the Government to intensify rice cropping through a summer rice crop. Recent policy changes have signaled opportunities to diversify production after harvesting the monsoon crop. Pulses, oilseeds and vegetables are now widely grown in rainfed areas and where summer irrigation is insufficient for a second rice crop. In irrigated areas, early maturing pulses are sometimes grown between the monsoon and the summer seasons. The growing demand for livestock feed suggests there may be opportunities to expand production of yellow corn and soybean, both of which require much less water than rice. Soybean has the added value of breaking the cereal rotation with benefits to soil fertility and pest and disease management (Denning et al., 2013).

2.5 Agricultural Policies and Strategies in Myanmar

Agricultural policy and planning in Myanmar is formulated within a context of policies, plans, and regulations that include the Framework for Economic and Social Reforms (FESR), the National Comprehensive Development Plan (NCDP), the Foreign Investment Law, and the National Export Strategy (NES). Each of these documents, although addressing general issues and not being specific to agriculture, contains several important implications for agricultural development.

The Framework for Economic and Social Reforms (FESR) prepared in 2012 targets reforms and strategies to improve food security, agricultural growth, welfare and incomes of farmers, farm laborers, and their dependent families. The FESR aims to improve productivity through increased extension services and government loans, removing barriers in supply chains, and moving toward demand-driven market support mechanisms (MOALI, 2016a).

The National Comprehensive Development Plan (NCDP) prepared in 2011 comprises a series of five-year plans covering 2011-2031. The long-term vision related to

agriculture and rural development seeks to “increase incomes and living standards of rural people who depend on the agriculture sector in Myanmar more than those of neighboring countries and keeping abreast of developed countries.”

2.6 Characteristics of Dry Zone

The dry zone is located in the central part of the country, situated at about 500 km north from the old capital Yangon. The Zone has merely 700 - 1,000 mm of annual precipitation since south-westerly monsoon was a way blown from Bengal Bay was intercepted by the mountain range of Rakhine that runs nearly south to northward at the western border of the country. Rainfall is concentrated in a few months of rainy season with erratic duration and with wide annual deviation in annual precipitation. This meteorological character not only very often brings about droughts with crop failure but also casual intense showers during mid-rainy season also result in floods in the watershed of Ayeyarwaddy River. Such climatic casualty makes the environment of agricultural production in country. The main concerns of dry zone are related to the fact that in the next decades the net primary production (NPP) would decline according to the estimation of FAO. In 2005-30, it would be decreased to 30% in Nyaung U and 44% in Meiktila (Kyi, 2016).

The Dry Zone is characterized by low rainfall with high variability and uneven distribution and the risks and uncertainties associated with rainfed agriculture are high. The majority of the farm-households in the Dry Zone cultivate a variety of crops in intercropping and sequence cropping systems. The principal crops are sesame, groundnut, pigeon pea, chickpea, sunflower, cotton and sorghum. Livestock is important to the Dry Zone economy and in particular sheep, goats and pigs.

The dry climate and erratic rainfall result in short cropping seasons and low yields. Very few opportunities exist locally for off-farm employment and alternative income generating activities from cottage industry are limited by low local demand. The lack of surplus cash available for purchased inputs and the relatively low quality of the land results in a vicious cycle of low-input low-output farming leading to a low volume of marketable produce. To survive most smallholders have to borrow money at high rates of interest from informal sources for both consumptive and productive needs.

Small-sized cottage industries as weaving, spinning, dying, masonry, carpentry, tapestry and their expertise have been developed as the dynasty emerged. Small-scaled as

it may be, these cottage industries have been rooted in almost all villages, providing precious cash-earning means for smallholder farmers and also landless villagers in rural areas. In most cases, these industrial activities have been developed as cottage industries and the products have been marketed within the villages or at nearby townships, though in some cases the scale has partly been escalated by the investment of surplus gained from agricultural production by lead-farmers. There is high potential of value addition by installing co-managed stores or introducing new techniques, but it has not been realized due to very limited assistance from administrative sources and other reasons (Kyi, 2016).

2.7 Water for Agriculture in Central Dry Zone

The Government of Myanmar has prioritized irrigation since the 1980s, with a major program of construction and irrigation development. In 2000, the government set a national target to make irrigation available for 25% of agricultural land, with an emphasis on provision of irrigation for summer paddy (Kahan, 2001). Estimates of total irrigated area in the Dry Zone (and nationally) vary very widely. Schemes are mainly gravity-fed canal systems from storage in dams or weirs; or pumped irrigation projects (PIP) drawing on rivers. There are smaller areas of groundwater irrigation, spate irrigation and small-scale water harvesting. Groundwater irrigation is only 5% of total area, but is growing at almost twice the rate of other types. Most large irrigation schemes have been funded by the government, with some support from FAO. In general, agricultural water supply is approached by NGOs and donors as a component of broadly based livelihood programs e.g. HDI-IV Integrated Community Development Project (ICDP) and CSEVI Shae Thot programs.

The performance of formal irrigation schemes has been sub-optimal. The actual area irrigated is much lower than nominal command area. A government report released by the Auditor General's Office in 2012, found that "Sixty-seven river water pumping stations have achieved 16.3% of their target, providing water to 48,833 acres out of the 299,895 acres originally planned", and that some reservoirs and diversion dams could not supply water at all. This is attributed to a wide range of issues including system design, operation and maintenance issues, availability of power for pumping, and inappropriate siting and soils (LIFT, 2012b). Many systems were designed to grow rice under flood conditions, and are insufficiently flexible for other crops; and there is a lack of extension of agronomic advice to assist farmers to make best use of irrigation (LIFT, 2011).

2.8 Crop Loss Due to Low Rainfall in Central Dry Zone

Given the nature of climate change droughts, hazards among others, the stresses they create for rural livelihoods have two major aspects: reduction of existing livelihood options, and perhaps more importantly in the short to medium run, greater volatility and unpredictability in streams of livelihoods benefits, especially in the semi-arid environments. The major uncertainties in specific locations that could be affected by climate change would push policy interventions to focus on improvements in adaptive capacity of disadvantaged rural populations rather than on identifying specifically how a given group of rural poor in a particular village or district will be affected by climate change. It is proved that there were crop losses by 81.43% of farm household in Nyaung U and by 94.29% of farm household in Meiktila. Out of 10 years, 3-4 years are probably facing the crop loss in selected survey areas of dry zone (Kyi, 2016).

Rainfall is a major concern for agrometeorology but it is variable in both space and time and many applications are more sensitive to the timing and amounts of rainfall through a season than they are to the total amount. With respect to this crop loss, development strategies and institutional interventions that focus simply on improving benefits to households without taking into account how households can address fluctuations in their livelihoods seem to be bad to address the impacts of climate change. On the one hand, they ignore the most important characteristics of climate-related stresses – increased risks in livelihoods. On the other hand, they ignore the very real concerns of the rural poor about preventing hunger and destitution. Given that many rural households have only limited access to markets – for reasons both of less developed infrastructure and of limited purchasing power, high levels of risks in the environment cannot in a vast number of cases be ameliorated by engaging in market exchange.

To strengthen the adaptive capacity of the rural poor, therefore, governments and other external actors need to strengthen and take advantage of the already existing strategies that many households and social groups use collectively or singly. Examining the environmental risks that rural populations have historically faced, their cultural responses to these risks, and the institutional configurations that facilitate individual and collective adaptation strategies is therefore a fruitful area of inquiry and policy analysis for generating effective coordination with external interventions (Kyi, 2016).

Lim, Spanger-Siegfried, Burton, Malone & Huq, (2005) note that national agricultural policy is developed in the context of local risks, needs, and capacities, as well

as international markets, tariffs, subsidies and trade agreements. Stakeholder participation in policy development is frequently recommended as a measure that can help to reduce the distance between national policy processes and the farm and community level.

2.9 Ongoing Project in Central Dry Zone

The Integrated Community Development Project (ICDP), assisted by UNDP, has been implemented in the Dry Zone since 1994 with the aim to improve food security and reduce poverty in 7 targeted townships. Since 2003 to date, a total of USD 8,341,378 investments have been made in this project. The project focuses on livelihood support activities such as the promotion of small scale irrigation schemes, the provision of improved seeds, the provision of financial and technical assistance to landless people for animal husbandry, and the development of capacity in local organizations for various technical and business skills. The ICDP is implementing project activities in 7 townships of the Dry Zone.

Some of the projects in the Dry Zone are aiming to improve the livelihoods of Dry Zone communities. FAO is supporting a project titled "Support to Special Rice Production in the Dry Zone, Mandalay Division". The objective of the project is to improve the quality and quantity of rice production in an area affected by chronically limited rain. Project activities cover extension services and training sessions to improve the cultivation and harvesting of rice. Particular attention is given to the introduction of new methods for the selection of seeds in order to achieve a stable and long-lasting effect on their quality. In addition to the multiplication of high quality seeds and the distribution of improved traditional seeds and seeds of new experimental varieties, mechanical tools, and especially water pumps for irrigation, are provided. The project area covers Meikhtilar and Yamethin in Mandalay Division, and is thereby not creating any duplication with the proposed approach (United Nations Development Program [UNDP], 2014).

At present, UN Habitat and Bridge Asia Japan (BAJ) are undertaking actions to increase water resources availability through pond renovation and deep tube well construction in some villages in the project target sites. Two International NGOs GRET and IDE have been implementing similar activities in several villages in Monywa Township in Sagaing Division and Myingyan Township in Mandalay Division, respectively.

A study for the 'Sustainable Agricultural and Rural Development for Poverty Reduction Programme in the Central Dry Zone' was supported by Japan International

Cooperation Agency (JICA) from 2008 to 2010. The development study was initiated to formulate a policy for reducing poverty in the Central Dry Zone. A project focusing on Rural Water Supply Technology in the Central Dry Zone was supported by JICA from 2007 to 2009 in Nyaung Oo Township. The objective of the project was to establish a reliable water supply system for and provide safe drinking water to local inhabitants through 20 new deep tube wells (200 to 300 meters in depth) as well as repairing 40 existing tube wells. In addition, the Afforestation Project in the Central Dry Zone has been implemented from 2003 to 2008 funded by JICA and led to the establishment of 1,619 ha of plantation in Nyaung Oo and Kyaukpadaung in the Mandalay Division. (UNDP, 2014).

The Asian Development Bank's (ADB) project supports fulfilling the government's Agriculture Development Strategy (ADS), 2018–2023 and the National Export Strategy, 2015-2019 by boosting competitiveness in value chains for rice, beans, pulses, and oilseeds in the Magway, Mandalay, and Sagaing regions in the central dry zone (CDZ) (MOALI, 2018). The project will increase climate resilience for critical rural infrastructure, promote quality and safety testing capacity, strengthen technical and institutional capacity for climate-smart agriculture (CSA), and create an enabling policy environment for climate-friendly agribusinesses. The project will reduce food insecurity and rural poverty, increase incomes and access to markets for smallholders and poor landless households, and improve resource efficiency and environmental sustainability for agribusinesses.

CHAPTER III

MATERIALS AND METHODS

3.1 General Description of the Study Area

Meiktila Township is situated in the Central Basin of Myanmar. It lies between North latitudes 20° 40' and 21° 00' and East longitudes 95° 30' and 96° 01'. Meiktila Township is one of thirty townships of Mandalay Region (Figure 3.1). It is composed of 58 village tracts. The township is bounded on the north by Mahlaing and Wundwin townships, on the east by Thazi Township, on the south by Pyawbwe Township, on the southwest by Natmauk Township, and on the west by Kyaukpadaung Township. The total boundary length of the township is about 115.5 miles (Myanmar Environment Institute [MEI], 2017). Total population of the township was 309,663 including 111,522 and 198,141 were urban and rural population, respectively (Department of Population [DoP], 2015).

3.1.1 Climate condition

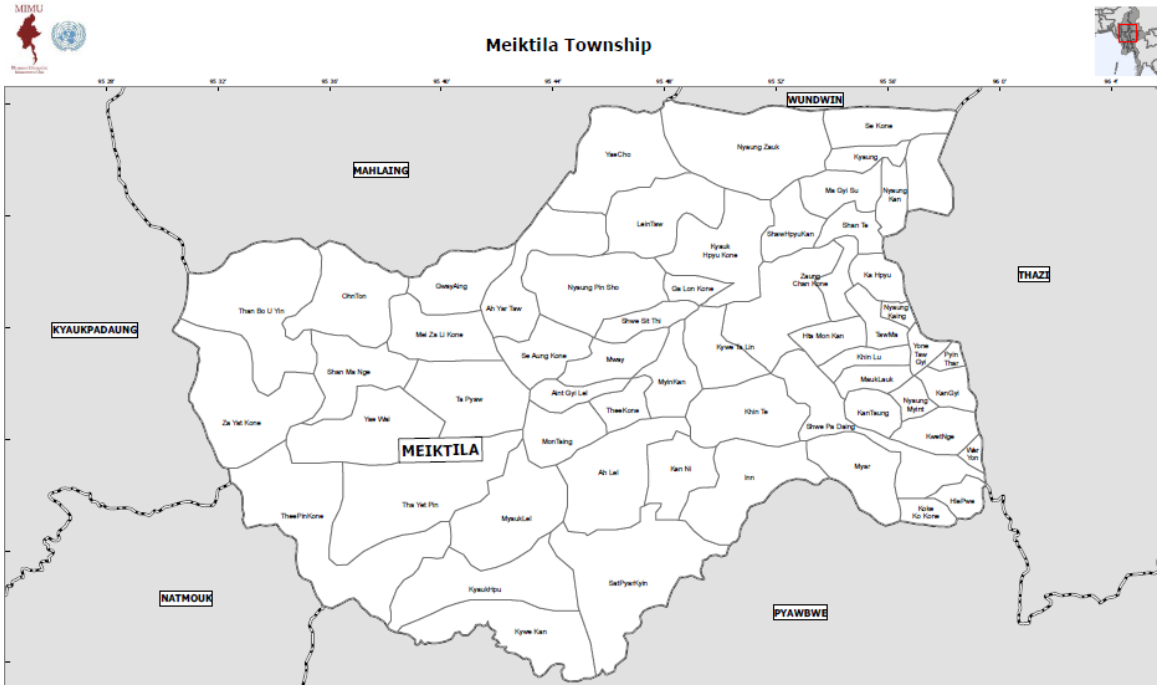
The rainfall pattern in Myanmar's central dry zone is diurnal, with drought occurring in July. Based on 10-year data on annual rainfall between 2009 and 2018, a fluctuation trend was found in Meiktila Township while lower rainfall was observed in 2012 and 2014 (Figure 3.2). Temperature data were recorded from 2009 to 2018.The average minimum temperature and average maximum temperature were about 33˚C and 22˚C, respectively (Figure 3.3).

3.1.2 Rice sown area and production in Meiktila Township

The highest rice sown area and production of wet season rice were found in 2010-2011 and the lowest was found in 2014-2015 (Table 3.1). In dry season, the highest rice sown area and production were found in 2010 and dry season rice could not cultivate in 2012 and 2014-2015. However, they cultivated dry season rice due to improvement of irrigation facilities in some areas starting from 2015 (Table 3.2).

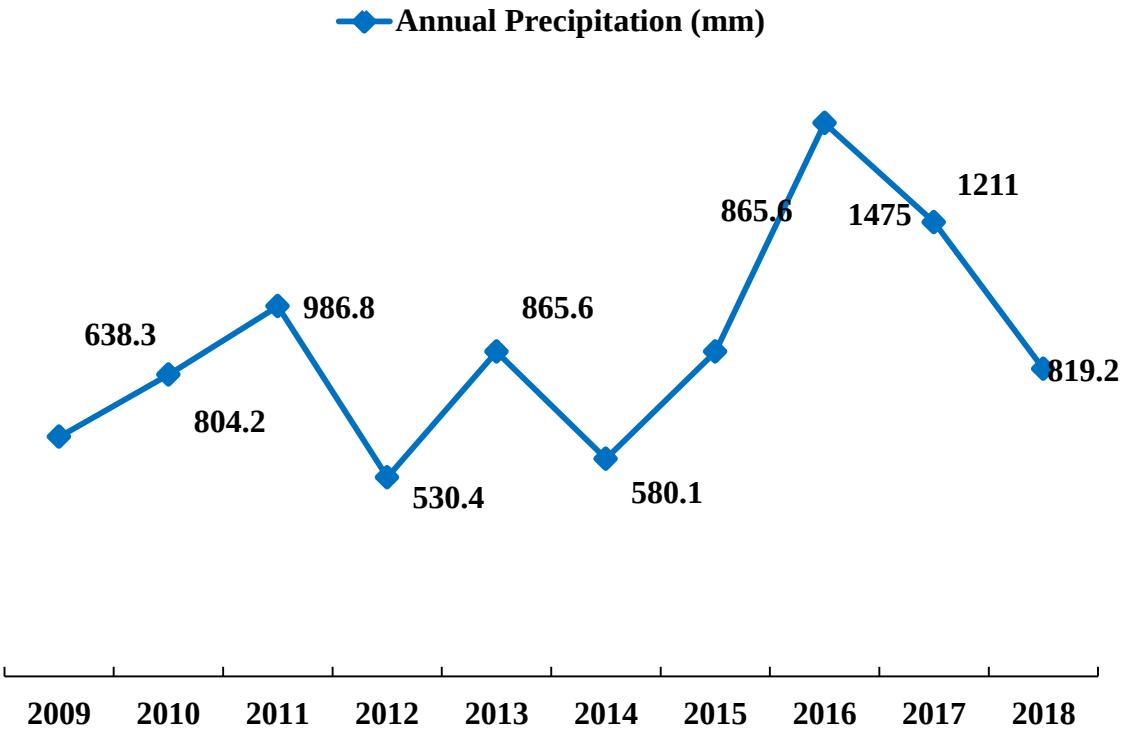
3.2 Data Collection and Analysis

Pilot survey was done by interviewing ten percent of the total respondents to collect the information about the changes of rice production systems between 2000 and 2018 in Meiktila Township in May 2018. The structured interview questionnaires was repaired based on the information collected from the pilot survey. Main research survey was conducted in June to September 2018. A purposive sampling method was adopted to select farm households for the interview survey. The sample size from each village was 40 respondents and therefore a total of 160 farm households cultivating rice based farming were selected from the study area (Table 3.3).



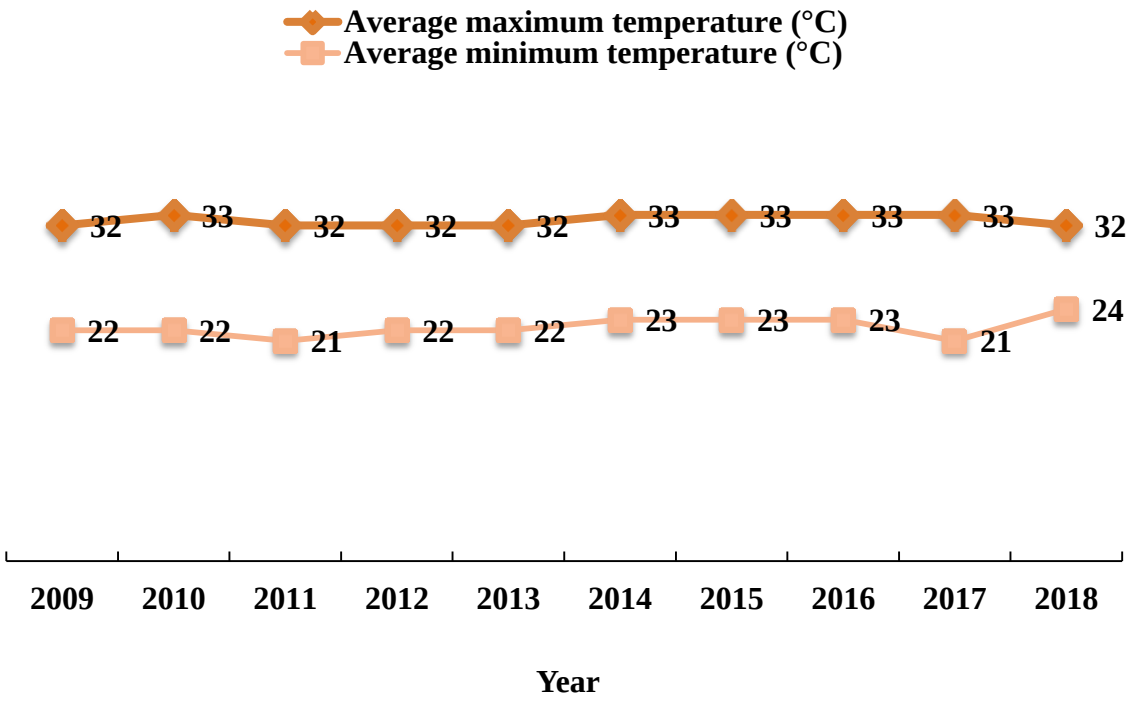
Source: Myanmar Information Management Unit [MIMU], 2008

Figure 3.1 Meiktila Township map



Source: DOA, 2018

Figure 3.2 Annual precipitations (mm) during 2009 and 2018 in Meiktila Township



Source: DOA, 2018

Figure 3.3 Average maximum and minimum temperature (°C) during 2009 and 2018 in Meiktila Township

Table 3.1 Cultivated areas (ha) of the major rice crops in Meiktila Township (2008-2018)

No.	Years	Rice (monsoon season)	Rice (summer season)
1	2008-2009	4340	169
2	2009-2010	4814	974
3	2010-2011	8735	819
4	2011-2012	5491	0
5	2012-2013	5638	422
6	2013-2014	4312	0
7	2014-2015	3940	0
8	2015-2016	5240	619
9	2016-2017	5678	681
10	2017-2018	5046	716

Source: DOA, 2018

Table 3.2 Production (MT) of the major rice crop in Meiktila Township (2008-2018)

No.	Years	Rice (monsoon season)	Rice (summer season)
1	2008-2009	15387	695
2	2009-2010	17174	4098
3	2010-2011	30428	3314
4	2011-2012	16582	0
5	2012-2013	18621	2038
6	2013-2014	13935	0
7	2014-2015	12747	0
8	2015-2016	16781	2601
9	2016-2017	15983	2851
10	2017-2018	16630	3115

Source: DOA, 2018

Table 3.3 Number of respondents and villages of study area

No.	Villages	No. of respondents
1	Net Kyi Gone	40
2	Kwat Nge	40
3	Zi Cho Gone	40
4	Da Hat Tann	40
	Total	160

Both primary and secondary data were used in this study. The primary data were collected from rice farmers with a structure interview questionnaire. Data were concerned with demographic data of the sample respondents in selected villages such as age, farm size, labours and their farming experiences. In addition, their landholding size and changes of rice production systems such as use of cultivars (hybrid/ high yielding/local),land preparation (draught animals/ machinery), sowing time, sowing method (direct seeded/ transplanted), irrigation methods (intermitted/flooded),amounts and kinds of fertilizer used (organic/chemical),pest infestation, methods of weed control, methods of harvesting (manual or machinery), yield, uses of rice straw residues, rice market, own consumption and climate threat for rice production were collected. The secondary data were obtained from DOA, Meiktila Township, MOALI.

3.3 Statistical Analysis

The qualitative data were encoded and quantitative or qualitative data were entered into the Microsoft Excel Program. The data were transferred to and analyzed by the Statistical Package for Social Science Program (SPSS) version 23 software. Descriptive analysis was used to explore the changes of rice production in the comparison between past and present. The paired-sample T Test was used to analyze the statistically differences of rice farming systems between past and present. The chi-square test was used to analyze the group of differences for the comparison of rice production systems between past and present.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Results

4.1.1 Demographic characteristics of respondents

The results of the survey indicated that 4.4% and 18.1% of the respondents were found in the age group of between 21and 30 years and between 31and 40 years. The middle age groups were composed of 23.1% of the respondents between 41 and 50 years and 25.6% of the respondents between 51 and 60 years. Moreover, the rest of the respondents (28.8%) were over 60 years (Table 4.1). Mean age of the respondents was 52.4 years; they still belong to the somewhat older age group. It indicates that only older members of the groups largely involved in rice farming.

The total farm size of the respondents in Meiktila Township can be viewed in Table (4.2). Average farm sizes of sample farmers in 2000 and 2018 were 2.6 and 2.4 ha, respectively. During 20 years, total farm size of the respondents were significantly changes ($t = 3.3$, $p < 0.05$). In past, the highest percentage (48.1%) of respondents possessed 0.2 to 2 ha and these respondents were increased to 55.6% in present. The owners of 2.1 to 4 and 4.1 to 6 ha farm size groups were 33.1% and 11.9%, respectively and the number of owners decreased to 30% and 10% in 2018. There was no change of land possession of the respondents possessed 8.1 to 10 ha. Only 1.3% of respondents owned more than 10 ha in the past.

Changes of total farm size of respondents were significantly varied according to group of farm size they possessed ($\chi^2 = 331.6$, $p < 0.05$). Four percent of the respondents who possessed the land of 0.2-2 ha in 2000 increased to 2.1-4 ha and 2.6% of respondents increased to 4.1-6 ha in 2018. In 2000, 26.4% of respondents who possessed 2.1-4 ha were decreased to 0.2-2 ha. Moreover, 21.1% who owned 4.1-6 ha decreased to 2.1-4 ha and 15.8% decreased their land size to 0.2-2 ha (Table 4.3).

Average rice cultivated areas were 1.5 and 1.3 ha in past and present, respectively. Changes of rice cultivated areas of respondents during 20 years were significantly different ($t = 2.8$, $p < 0.05$). In 2000, the highest percentage of respondents (75%) possessed 0.2 to 2 ha and that farm size of respondent percent increased to 81.3% in 2018. The percentages of respondents (21.9%) owned 2.1 to 4 ha of rice areas in past and decreased to 17.5% at present (Table 4.4).

Table 4.1 Age groups of respondents in Meiktila Township

Age group (years)	Respondents (n=160)	
	Frequency	Percentage
21-30	7	4.4
31-40	29	18.1
41-50	37	23.1
51-60	41	25.6
over 60	46	28.8
Total	160	100.0
Mean	52.4	

Table 4.2 Total farm size of the respondents between 2000 and 2018 in Meiktila Township

Total farm size (ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0.2-2	77	48.1	89	55.6
2.1-4	53	33.1	48	30.0
4.1-6	19	11.9	16	10.0
6.1-8	7	4.4	5	3.1
8.1-10	2	1.3	2	1.3
over 10	2	1.3	-	-
Total	160	100.0	160	100.0
Mean	2.6		2.4	
Minimum	0.2		0.4	
Maximum	12.0		10.0	
t value	3.3 *			

* = significance at 5% level

Table 4.3 Changes of total farm size of respondents between 2000 and 2018 in Meiktila Township

Total farm size (ha) (2000)	Respondents (n=160)				
	Total farm size (ha) (2018)				
	0.2-2.0	2.1-4	4.1-6	6.1-8	8.1-10
0.2-2	72 (93.5)	3 (3.9)	2 (2.6)	0 (0.0)	0 (0.0)
2.1-4	14 (26.4)	39 (73.6)	0 (0.0)	0 (0.0)	0 (0.0)
4.1-6	3 (15.8)	4 (21.1)	12 (63.2)	0 (0.0)	0 (0.0)
6.1-8	0 (0.0)	1 (14.3)	0 (0.0)	5 (71.4)	1 (14.3)
8.1-10	0 (0.0)	1 (50.0)	0 (0.0)	0 (0.0)	1 (50.0)
Over 10	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)
χ^2	331.6*				

Figures in the parentheses are percentages.

* = significance at 5% level

Table 4.4 Rice areas of the respondents between 2000 and 2018 in Meiktila Township

Paddy area (ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0.2-2	120	75.0	130	81.3
2.1-4	35	21.9	28	17.5
4.1-6	2	1.3	1	0.6
over 6	3	1.9	1	0.6
Total	160	100.0	160	100.0
Mean	1.5		1.3	
Minimum	0.2		0.2	
Maximum	8.0		7.2	
t value	2.8*			

* = significance at 5% level

Changes of rice areas of respondents were significantly varied according to groups of rice areas they possessed (χ^2 = 193.9, p < 0.05). Four percent of the respondents who possessed the land of 0.2-2 ha in 2000 increased to 2.1-4 ha in 2018. The respondents (42.9%) who possessed 2.1-4 ha decreased their lands to 0.2-2 ha. Similarly, 50% of respondents who owned their rice areas decreased to 2.1-4 ha in 2018 (Table 4.5).

Average rice plots were 1.7 and 1.5 plots in past and present, respectively. Changing rice plots of the respondents during 20 years were not significantly different (t = 1.6). The majority of the respondents (81.9%) have 1-2 rice plots in 2000 and these respondents increased to 85.0% in 2018. In 2000, 3-4 rice plots were owned by the respondents (16.9%) whereas at present only 15% of them possessed these plots. Only 1.3% of respondents have 5-6 rice plots in 2018 (Table 4.6).

However, the changes of rice plots owned by respondents were significantly varied according to group of rice plots they possessed (χ^2 = 71.3, p < 0.05). Only 3.8% of respondents have 1-2 rice plots in 2000 and increased to 3-4 rice plots in 2018. The percentages of respondents (33.3%) who have 3-4 rice plots decreased to 1-2 rice plots and then 50% of respondents who have 5-6 rice plots decreased to 3-4 and also 50% to 1-2 rice plots (Table 4.7).

In 2000, rice field compositions of respondents (63.1%) were aggregated and these percentages of respondents increased to 68.1% in 2018. Rice field composition of respondents (36.9%) were scattered in past and decreased to 31.9% in present (Table 4.8).

The changes of rice fields composition of respondents were highly significantly varied according to group of rice fields composition they possessed (χ^2 = 84.8, p < 0.05). Six percent of respondents whose rice fields were aggregated in 2000 changed to scattered fields in 2018. In 2000, 23.7% of the respondents who owned rice fields were scattered and changed to aggregate fields in 2018 (Table 4.9). In study area, rice fields' topography and soil conditions of rice fields of all respondents were flat, clay soil with medium fertility in both 2000 and 2018.

4.1.2 Changes of cultural practices in wet season

4.1.2.1 Cropping pattern

In 2000, all respondents (100%) cultivated rice as mono-crop per year but 66.9% of respondents changed to cultivate double cropping of rice per year in 2018. Among all respondents, only 2.5% of respondents were irregularly cultivated rice depends on water availability (Table 4.10).

Table 4.5 Changes of rice areas of sample farmers between 2000 and 2018 in Meiktila Township

Rice area (ha) (2000)	Respondents (n=160)			
	Rice area (ha) (2018)			
	0.2-2.0	2.1-4	4.1-6	over 6
0.2-2	115 (95.8)	5 (4.2)	0 (0.0)	0 (0.0)
2.1-4	15 (42.9)	20 (57.1)	0 (0.0)	0 (0.0)
4.1-6	0 (0.0)	1 (50.0)	1 (50.0)	0 (0.0)
over 6	0 (0.0)	2 (66.7)	0 (0.0)	1 (33.3)
χ^2	193.9*			

Figures in the parentheses are percentages.
* = significance at 5% level

Table 4.6 Rice plots of the respondents between 2000 and 2018 in Meiktila Township

Rice plots	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
1-2	131	81.9	136	85.0
3-4	27	16.9	24	15.0
5-6	2	1.3	-	-
Total	160	100.0	160	100.0
Mean	1.7		1.5	
Minimum	1.0		1.0	
Maximum	6.0		4.0	
t value	1.6^{ns}			

ns = non-significant

Table 4.7 Changes of rice plots of sample farmers between 2000 and 2018 in Meiktila Township

Rice plots (2000)	Respondents (n=160)	
	Rice plots (2018)	
	1-2	3-4
1-2	126 (96.2)	5 (3.8)
3-4	9 (33.3)	18 (66.7)
5-6	1 (50.0)	1 (50.0)
χ^2	71.3*	

Figures in the parentheses are percentages.

* = significance at 5% level

Table 4.8 Composition of rice fields of the respondents between 2000 and 2018 in Meiktila Township

Composition of rice fields	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Aggregated	101	63.1	109	68.1
Scattered	59	36.9	51	31.9
Total	160	100.0	160	100.0

Table 4.9 Changes of composition of rice fields of respondents between 2000 and 2018 in Meiktila Township

Composition of rice fields (2000)	Respondents (n=160)	
	Composition of rice fields (2018)	
	Aggregated	Scattered
Aggregated	95 (94.1)	6 (5.9)
Scattered	14 (23.7)	45 (76.3)
χ^2	84.8*	

Figures in the parentheses are percentages.

* = significance at 5% level

Table 4.10 Cropping pattern of rice of the respondents between 2000 and 2018 in Meiktila Township

Rice cropping pattern	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Mono-cropping	160	100.0	49	30.6
Double-cropping	-	-	107	66.9
Irregular	-	-	4	2.5
Total	160	100.0	160	100.0

Most of the respondents (87.5%) cultivated two crops per year with rice-upland crops (sesame, beans etc.) in 2000 and decreased to 25% in 2018. In past, 12.5% of respondents were practiced rice-fallow and these percentages of respondents decreased to 6.9% in present. Most of the respondents (65.6%) cultivated rice-rice in present but nobody practiced this pattern in the past (Table 4.11). The changes of rice-based cropping patterns of respondents were highly significantly varied according to groups of rice-based cropping patterns they practiced ($\chi^2 = 22.1$, $p < 0.01$). Sixty percent of respondents who cultivated rice-fallow in 2000 changed to cultivate rice-rice pattern in 2018 and each 5% of respondents changed to cultivate rice-upland and erratic pattern. The respondents who cultivated rice-upland patterns in 2000 were changed 66.4% to rice-rice, 3.6% to rice-fallow and 2.1% to erratic pattern ,respectively in 2018 (Table 4.12).

Most of the respondents (61.3%) cultivated food crops (sesame, bean etc.) in 2000 and increased to 61.9% in 2018. Only 0.6% of respondent was cultivated perennial crop (mango) in present. In past, 38.8% of respondents did not grow other crops and this percentage decreased to 37.5% in present (Table 4.13). The changes of other crops were significantly varied according to group of other crops they sown ($\chi^2=77.7$, $p < 0.01$). Eleven percent of respondents who cultivated food crops in 2000 did not cultivate any other crops in 2018. The respondents (19.4%) who did not grow other crops in past changed to cultivate food crops in present and only 1.6% of them changed to perennial crops (Table 4.14).

4.1.2.2 Seed selection

Most of the respondents (95.6%) used traditional rice varieties for wet season in 2000 and decreased to 1.9% in 2018. Four percent of respondents used improved rice varieties in past and these respondents increased to 93.1% in present. Because of high yield and price, most of the respondents changed to grow improved rice varieties. Only 5% of respondents used hybrid rice varieties at present. A few percentages of respondents (0.6%) used certified seeds for wet season in 2000 and increased to 63.1% in 2018. Most of the respondents (99.4%) used non certified seed (preserving seed) in past and decreased to 36.9% at present. Most of the respondents (95.6%) grown traditional long duration varieties in the past and in present these respondents decreased to 1.9%. Four percent of respondents cultivated medium duration varieties in the past and increased to 93.1% in present (Table 4.15). The changes of rice varieties for wet season used by respondents were not significantly varied according to group of rice varieties they grown ($\chi^2=0.5$). Most of the respondents (92.8%) used traditional rice varieties in 2000 and changed to use improved rice varieties and also 5.2% of these respondents changed to hybrid varieties in 2018 (Table 4.16).

Table 4.11 Rice-based cropping patterns of the respondents between 2000 and 2018 in Meiktila Township

Rice-based cropping patterns	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Rice-fallow	20	12.5	11	6.9
Rice-rice	-	-	105	65.6
Rice-upland	140	87.5	40	25.0
Irregular	-	-	4	2.5
Total	160	100.0	160	100.0

Table 4.12 Changes of rice-based cropping patterns of respondents between 2000 and 2018 in Meiktila Township

Rice-based cropping patterns (2000)	Respondents (n=160)			
	Rice-based cropping patterns (2018)			
	Rice-fallow	Rice-rice	Rice-upland	Erratic
Rice-fallow	6 (30.0)	12 (60.0)	1 (5.0)	1 (5.0)
Rice-upland	5 (3.6)	93 (66.4)	39 (27.9)	3 (2.1)
χ^2	22.1**			

Figures in the parentheses are percentages.

**= significance at 1% level

Table 4.13 Other crops of the respondents between 2000 and 2018 in Meiktila Township

Other crops	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Food crop	98	61.3	99	61.9
Perennial	-	-	1	0.6
None	62	38.8	60	37.5
Total	160	100.0	160	100.0

Table 4.14 Changes of other crops of respondents between 2000 and 2018 in Meiktila Township

Other Crops (2000)	Respondents (n=160)		
	Other crops (2018)		
	Food crop	Perennial	None
Food crop	87 (88.8)	0 (0.0)	11 (11.2)
None	12 (19.4)	1 (1.6)	49 (79.0)
χ^2		77.7**	

Figures in the parentheses are percentages.
** = significance at 1% level

Table 4.15 Rice varieties for wet season used by respondents in 2000 and 2018 in Meiktila Township

Items	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Rice variety				
Hybrid	-	-	8	5.0
Improved	7	4.4	149	93.1
Traditional	153	95.6	3	1.9
Total	160	100.0	160	100.0
Seed type				
Certified	1	0.6	101	63.1
Non certified	159	99.4	59	36.9
Total	160	100.0	160	100.0
Duration of rice variety				
Long	153	95.6	3	1.9
Medium	6	3.8	149	93.1
Short	1	0.6	8	5.0
Total	160	100.0	160	100.0

Table 4.16 Changes of rice varieties for wet season used by respondents between 2000 and 2018 in Meiktila Township

Rice varieties (2000)	Respondents (n=160)		
	Rice varieties (2018)		
	Hybrid	Improved	Traditional
Improved	0 (0.0)	7 (100.0)	0 (0.0)
Traditional	8 (5.2)	142 (92.8)	3 (2.0)
χ^2		0.5^{ns}	

Figures in the parentheses are percentages.

ns = non-significant

Changes of seed types for wet season were not significantly varied according to group of their preference (χ^2=0.5), but only a small group was varied. The percentage (62.9%) of respondents used non certified seed in 2000 and these respondents changed to use certified seed in 2018 (Table 4.17). Although the changes of duration of rice variety for wet season of respondents were not significantly varied according to group of their preference (χ^2=0.5), some groups were varied. The majority of respondents (92.8%) cultivated long duration varieties in 2000 and these respondents changed to medium duration varieties and 5.2% also changed to short duration varieties in present (Table 4.18). Most of the respondents (95%) traditionally used their local varieties due to easy to access in 2000. A few percentages (0.6%) of respondent were chosen rice varieties with the reason of eating quality in past and increased to 20% in present. Although four percentages of respondents used rice varieties due to the reason of high yield in past, in present 63.8% of respondents more considered more on the reason of high yield. Only 8.8% of respondents' reason was changed to better price in present (Table 4.19).

Although the changes of varietal preference of respondents for wet season were not significantly varied according to group of their preference (χ^2=13.6,), only a small group was varied. According to easy to access of local varieties, the majority of the respondents used their local varieties in past, but at present this reason was changed to better price (7.9%), short duration (7.9%), eating quality (21.1%) and high yield (63.2%), respectively. In 2000, 100% of respondents used short duration varieties because of water insufficient and this reason changed to better price in 2018. The respondents (100%) chose eating quality in past and in present this reason of respondents was changed to high yield. Seventeen percent of respondents used high yield varieties in past and this reason was changed to better price at present (Table 4.20). In the study area, all respondents obtained varietal information from fellow farmers in past and decreased to 48.8% in present. Fifty one percent of respondents got variety information from extension workers in present (Table 4.21).

4.1.2.3 Land preparation

In 2000, 97.5% of respondents prepared land by using draught power but 6.9% of respondents used this practice in 2018. A few percentage (1.3%) of respondents used machine in past and significantly increased to 93.5% in present. Only 1.3% of respondents prepared land by manual in past. Nearly all respondents (98.8%) did not use machine for land preparation in 2000 whereas 7.5% of respondents still used in 2018. In past, the respondents (0.6%) who owned tractor were increased to 6.3% in present. Very few percentages of respondents (0.6%) hired tractor from private services for land preparation in past and at present the respondents increased to 86.3% (Table 4.22).

Table 4.17 Changes of seed types for wet season of respondents between 2000 and 2018 in Meiktila Township

Seed types (2000)	Respondents (n=160)	
	Seed types (2018)	
	Certified	Non certified
Certified	1 (100.0)	0 (0.0)
Non certified	100 (62.9)	59 (37.1)
χ^2	0.5^{ns}	

Figures in the parentheses are percentages.

ns = non-significant

Table 4.18 Changes of duration of rice variety for wet season of respondents between 2000 and 2018 in Meiktila Township

Duration of rice variety (2000)	Respondents (n=160)		
	Duration of rice variety (2018)		
	Long	Medium	Short
Long	3 (2.0)	142 (92.8)	8 (5.2)
Medium	0 (0.0)	6 (100.0)	0 (0.0)
Short	0 (0.0)	1 (100.0)	0 (0.0)
χ^2		0.5^{ns}	

Figures in the parentheses are percentages.

ns = non-significant

Table 4.19 Varietal preferences of respondents for wet season between 2000 and 2018 in Meiktila Township

Varietal preferences	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Better price	-	-	14	8.8
Availability	152	95.0	-	-
Short duration	1	0.6	12	7.5
Eating quality	1	0.6	32	20.0
High yield	6	3.8	102	63.8
Total	160	100.0	160	100.0

Table 4.20 Changes of varietal preferences of respondents for wet season between 2000 and 2018 in Meiktila Township

Varietal preferences (2000)	Respondents (n=160)			
	Varietal preferences (2018)			
	Better price	Short duration	Eating quality	High yield
Availability	12 (7.9)	12 (7.9)	32 (21.1)	96 (63.2)
Short duration	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)
Eating quality	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)
High yield	1 (16.7)	0 (0.0)	0 (0.0)	5 (83.3)
χ^2	13.6^{ns}			

Figures in the parentheses are percentages.

ns = non-significant

Table 4.21 Sources of varietal information for wet season of respondents between 2000 and 2018 in Meiktila Township

Sources of varietal information	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Extension workers	-	-	82	51.3
Fellow farmers	160	100.0	78	48.8
Total	160	100.0	160	100.0

Table 4.22 Land preparation of respondents between 2000 and 2018 in Meiktila Township

Items	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Land preparation				
Draught power	156	97.5	11	6.9
Manual	2	1.3	-	-
Mechanical	2	1.3	149	93.1
Total	160	100.0	160	100.0
Source of machine for land preparation				
Not mechanized	158	98.8	12	7.5
Own tractor	1	0.6	10	6.3
Private services	1	0.6	138	86.3
Total	160	100.0	160	100.0

Although the changes in land preparation of respondents for wet season were not significantly varied according to group of land preparation they practiced (χ^2=0.3), some groups were varied. In 2000, the majority of respondents (92.9%) used draught power for land preparation due to machine was not available in this area and changed to use machine in 2018 (Table 4.23). Family labours for land preparation used by respondents during 20 years were not significantly different (t = 1.2). All respondents did not use family labours for land preparation in 2000 and in 2018 (Table 4.24).

Changes in sources of machine for land preparation used by respondents were significantly varied according to group of machine sources they used (χ^2=15.2, $p < 0.05$). Eighty seven percent of respondents haven't prepared land by machine in 2000 and these respondents changed to use machine for land preparation by hiring from private services and 5.7% of them had own tractor in 2018 (Table 4.25). Although more than half of the respondents (66.9%) done two strokes of tillage operation in 2000, this operation was used by 81.9% in 2018. Three strokes of tillage operation was done by 30.6% of respondents in past and decreased to 13.8% in present. Three percent of respondents operated one stroke of tillage in past and these respondents increased to 4.4% at present (Table 4.26).

Changes of frequency of tillage operation for wet season practiced by respondents were significantly varied according to group of tillage operation they done (χ^2=126.4, $p < 0.01$). A few percentages (2.8%) of respondents operated two strokes of tillage in past changed to three strokes of tillage in present and the rest (94.4%) continued two strokes of tillage operation. And also 2.8% of them changed to use one stroke of tillage operation in present. Thirty nine percent of the respondents who practiced three strokes of tillage operation in 2000 continued to use this practice in 2018, however, 61.2% of them changed to two strokes of tillage operation in 2018 (Table 4.27).

Sixty nine percent of respondents used draught power for land leveling in 2000 and increased to 87.5% in 2018. Leveling was not done by 15.6% of respondents in past and those percentage decreased to 12.5% in present. Only 15% of respondents used machine for land leveling in 2000 (Table 4.28). Changes of land leveling for wet season practiced by respondents were significantly varied according to group of leveling they done (χ^2=109.5, $p < 0.01$). The respondents who practiced land leveling by animal drawn implement in past changed to machine (16.4%) and no leveling (4.3%) at present. Ninety five percent of respondents who did not level in 2000 still continued to use this practice and only 5% changed to use machine for leveling (Table 4.29).

Table 4.23 Changes of land preparation methods of respondents between 2000 and 2018 in Meiktila Township

Land preparation methods (2000)	Respondents (n=160)	
	Land preparation methods (2018)	
	Animal	Mechanical
Animal	11 (7.1)	145 (92.9)
Manual	0 (0.0)	2 (100.0)
Mechanical	0 (0.0)	2 (100.0)
χ^2	0.3^{ns}	

Figures in the parentheses are percentages.

ns = non-significant

Table 4.24 Family labours for land preparation used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours for land preparation (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	158	98.8	160	100.0
0.1-1	2	1.2	-	-
Total	160	100.0	160	100.0
Mean	0.0		0.0	
Minimum	0.0		0.0	
Maximum	0.6		0.0	
t value	1.2^{ns}			

ns = non-significant

Table 4.25 Changes of sources of machine for land preparation used by respondents between 2000 and 2018 in Meiktila Township

Sources of machine for land preparation (2000)	Respondents (n=160)		
	Sources of machine for land preparation (2018)		
	Not mechanized	Own tractor	Private services
Not mechanized	12 (7.6)	9 (5.7)	137 (86.7)
Own tractor	0 (0.0)	1 (100.0)	0 (0.0)
Private services	0 (0.0)	0 (0.0)	1 (100.0)
χ^2		15.2*	

Figures in the parentheses are percentages.

* = significance at 5% level

Table 4.26 Frequency of tillage operation for wet season practiced by respondents between 2000 and 2018 in Meiktila Township

Frequency of tillage operation	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
One stroke	4	2.5	7	4.4
Two strokes	107	66.9	131	81.9
Three strokes	49	30.6	22	13.8
Total	160	100.0	160	100.0

Table 4.27 Changes of frequency of tillage operation for wet season practiced by respondents between 2000 and 2018 in Meiktila Township

Frequency of tillage operation (2000)	Respondents (n=160)		
	Tillage operation (2018)		
	One stroke	Two strokes	Three strokes
One stroke	4 (100.0)	0 (0.0)	0 (0.0)
Two strokes	3 (2.8)	101 (94.4)	3 (2.8)
Three strokes	0 (0.0)	30 (61.2)	19 (38.8)
χ^2		126.4**	

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.28 Land leveling for wet season practiced by respondents between 2000 and 2018 in Meiktila Township

Land leveling	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Draught power	111	69.4	140	87.5
Mechanical	24	15.0	-	-
No leveling	25	15.6	20	12.5
Total	160	100.0	160	100.0

Table 4.29 Changes of land leveling for wet season practiced by respondents between 2000 and 2018 in Meiktila Township

Land leveling (2000)	Respondents (n=160)		
	Land leveling (2018)		
	Draught power	Mechanical	No leveling
Draught power	111 (79.3%)	23 (16.4%)	6 (4.3%)
No leveling	0 (0.0%)	1 (5.0%)	19 (95.0%)
χ^2		109.5**	

Figures in the parentheses are percentages.

** = significance at 1% level

4.1.2.4 Rice establishment

Almost all respondents (98.1%) transplanted rice by manual in 2000 and decreased to 96.3% in 2018. Only 1.9% of respondents used seed broadcasting method in past and in present increased to 3.8% (Table 4.30).

Changes of establishment methods for wet season practiced by respondents were significantly varied according to group of establishment methods they practiced (χ^2=7.4, $p < 0.05$). In 2000, 66.7% of respondents practiced seed broadcasting methods and changed to transplanting methods in 2018. Transplanting method was used by 3.2% of respondents in past and in present changed to seed broadcasting methods due to labours shortage Among the respondents who practiced transplanting method in 2000, 96.8% of them were still using transplanting in 2018 (Table 4.31).

For wet season rice establishment, average family labours was one person per ha in 2000 and 2018, respectively. Changing family labours for wet season rice establishment used by respondents during 20 years were not significantly different ($t = 0.4$). In 2000, eighty one percent of respondents did not work with their family members in rice establishment and these respondents increased to 82.5% in 2018. Only (0.6%) of respondents used more than 10 persons per ha in past and (0.6%) of respondent used family labours within the range of (7-8) persons per ha in present. About the same percentage (8.8%) of respondents used their family labours (1-2) or (3-4) persons per ha in rice planting during 2000 to 2018 (Table 4.32).

Changes of family labours for rice establishment in wet season used by respondents were significantly varied according to group of family labours they used (χ^2=251.7, $p < 0.01$). In 2000, the respondents who did not use family labours were used (2.3%) within the range of (1-2) persons per ha and 2.3% of them used (3-4) and also (0.8%) used within the range of (7-8) persons per ha in 2018. Twenty eight percent of respondents who used family labours within the range of (1-2) persons per ha in past and these respondents changed to use the range of (3-4) persons per ha, 50% of them used (1-2) persons per ha and 21.4% of them did not use family labours in present. In 2000, 14.3% of respondents used (3-4) persons per ha and changed to use (1-2) persons per ha and 35.7% of them did not use family labours in 2018. Only one respondent used more than 10 persons per ha in past and did not use at present (Table 4.33).

Table 4.30 Establishment methods for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Establishment methods	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Broadcasting	3	1.9	6	3.8
Transplanting	157	98.1	154	96.3
Total	160	100.0	160	100.0

Table 4.31 Changes of establishment methods for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Establishment methods (2000)	Respondents (n=160)	
	Establishment methods (2018)	
	Broadcasting	Transplanting
Broadcasting	1 (33.3)	2 (66.7)
Transplanting	5 (3.2)	152 (96.8)
χ^2	7.4*	

Figures in the parentheses are percentages.

* = significance at 5% level

Table 4.32 Family labours for rice establishment in wet season used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	130	81.3	132	82.5
1-2	14	8.8	12	7.5
3-4	14	8.8	14	8.8
5-6	1	0.6	1	0.6
7-8	-	-	1	0.6
over 10	1	0.6	-	-
Total	160	100.0	160	100.0
Mean	1.0		1.0	
Minimum	0.0		0.0	
Maximum	18.0		7.0	
t value	0.4^{ns}			

ns = non-significant

Table 4.33 Changes of family labours for rice establishment in wet season used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (2000) (person/ha)	Respondents (n=160)				
	No. of family labours (2018) (person/ha)				
	0	1-2	3-4	5-6	7-8
0	123 (94.6)	3 (2.3)	3 (2.3)	0 (0.0)	1 (0.8)
1-2	3 (21.4)	7 (50.0)	4 (28.6)	0 (0.0)	0 (0.0)
3-4	5 (35.7)	2 (14.3)	7 (50.0)	0 (0.0)	0 (0.0)
5-6	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)
Over 10	1 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
χ^2	251.7**				

Figures in the parentheses are percentages.

** = significance at 1% level

For wet season rice establishment, average hired labours were 20 and 23 persons per ha in 2000 and 2018, respectively. Changing hired labours for wet season rice establishment used by respondents during 20 years were significantly different ($t = -5.9$, $p < 0.01$). It was found that only few respondents (1.3% to 6%) hired less than 10 labours for rice planting during 20 years. Within the range of (10-20) persons per ha was hired by 49.4% of respondents in past and in present the respondents decreased to 26.3%. The respondents (36.9%) who hired (21-30) persons per ha in past increased to 57.5% in present. Only 5.6% of respondents used hired labours within the range of (31-40) persons per ha in past and increased to 11.9% at present (Table 4.34).

Changes of hired labours for rice establishment in wet season were significantly varied according to group of hired labours they used ($\chi^2=109.5$, $p < 0.01$). In 2000, the respondents (66.7%) who did not use hired labours were changed to use with the range of (10-20) persons per ha and 33.3% of them used (21-30) persons per ha in 2018. Among the respondents who hired less than 10 persons per ha in past changed to use within the range of (10-20) persons per ha (70%), (31-40) persons per ha (10%) and then less than 10 persons per ha (20%) in present Significant changes of hired labours was largely due to hire more labours from (10-20) to (20-30) persons per ha during 20 years made by 52% of the respondents (Table 4.35).

Very few percentages (1.3%) of respondents changed to use new establishment method by getting information from extension workers (1.3%) and labours shortage (3.1%) in 2018. Almost all of the respondents (95.6%) did not use new establishment method at present (Table 4.36).More than 14 days old rice seedlings were transplanted by 4% of respondents in 2000 and 41.9% in 2018. Most of respondents (94.4%) who used older than 28 days rice seedling in past decreased to 54.4% in present. Only 1.9% of respondents did not use transplanting method in past and increased to 3.8% at present (Table 4.37).

Changes of seedling age for wet season rice transplanted by respondents were significantly varied according to group of sources for new establishment methods they used ($\chi^2=320$, $p < 0.05$). Changes of seedling age usage was found due to 40.4% of respondents who normally used greater than 28 days old seedlings changed to use 14 to 28 days old seedlings in 2018 (Table 4.38). Almost all of the respondents (94.4%) practiced random spatial arrangement in past and in present this percentage decreased to 52.5%. In 2000, 5.6% of respondents transplanted in rows arrangement and increased to 46.9% in 2018. Only 0.6% of respondents who did not practiced consistently spatial arrangement based on labours availability when rice transplanting in present (Table 4.39).

Table 4.34 Hired labours for rice establishment in wet season used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	3	1.9	2	1.3
<10	10	6.3	5	3.1
10-20	79	49.4	42	26.3
21-30	59	36.9	92	57.5
31-40	9	5.6	19	11.9
Total	160	100.0	160	100.0
Mean	20.0		23.0	
Minimum	0.0		0.0	
Maximum	39.0		39.0	
t value	-5.9**			

** = significance at 1% level

Table 4.35 Changes of hired labours for rice establishment in wet season used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (2000) (person/ha)	Respondents (n=160)				
	No. of hired labours (2018) (person/ha)				
	0	<10	10-20	21-30	31-40
0	0 (0.0)	0 (0.0)	2 (66.7)	1 (33.3)	0 (0.0)
<10	0 (0.0)	2 (20.0)	7 (70.0)	0 (0.0)	1 (10.0)
10-20	1 (1.3)	2 (2.5)	31 (39.2)	41 (51.9)	4 (5.1)
21-30	1 (1.7)	0 (0.0)	2 (3.4)	50 (84.7)	6 (10.2)
31-40	0 (0.0)	1 (11.1)	0 (0.0)	0 (0.0)	8 (88.9)
χ^2	109.5**				

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.36 Reasons for changing new establishment methods used by respondents in 2018 in Meiktila Township

Reasons	Respondents (n=160)	
	2018	
	Frequency	Percentage
Extension workers	2	1.3
Labours shortage	5	3.1
No changes	153	95.6
Total	160	100.0

Table 4.37 Seedling age for wet season rice transplanted by respondents between 2000 and 2018 in Meiktila Township

Seedling age (Days)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
14-28	6	3.8	67	41.9
Older than 28	151	94.4	87	54.4
Not transplanting	3	1.9	6	3.8
Total	160	100.0	160	100.0

Table 4.38 Changes of seedling age for wet season rice transplanted by respondents between 2000 and 2018 in Meiktila Township

Seedling age (2000) (Days)	Respondents (n=160)		
	Seedling age (2018) (Days)		
	14-28	Older than 28	No transplanting
14-28	4 (66.7)	2 (33.3)	0 (0.0)
Older than 28	61 (40.4)	85 (56.3)	5 (3.3)
No transplanting	2 (66.7)	0 (0.0)	1 (33.3)
χ^2		10.9*	

Figures in the parentheses are percentages.
* = significance at 5% level

Table 4.39 Spatial arrangement of transplanting for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Spatial arrangement	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Random	151	94.4	84	52.5
Row planting	9	5.6	75	46.9
Erratic	-	-	1	0.6
Total	160	100.0	160	100.0

Changes of spatial arrangement for wet season rice practiced by respondents were significantly varied according to group of spatial arrangement they practiced (χ^2=6.7, $p < 0.05$). Forty four percent of respondents transplanted with random spatial arrangement in past and these respondents changed to use structure (rows) arrangement. Structure (rows) arrangement was practiced by 88.9% of respondents, while 11.1% changed to practice random spatial arrangement in 2018 (Table 4.40).

4.1.2.5 Water management

Ninety four percent of respondents planted their rice field by supplying permanent flooding in past whereas in present farmers were decreased to 36.3%. In 2000, a few percentages of respondents practiced intermittent irrigation and in 2018 increased to 63.8% (Table 4.41). Changes of water management for wet season rice practiced by respondents were significantly varied according to group of water management they practiced (χ^2=5.4, $p < 0.05$). Chi-square analysis showed that permanent flooding was practiced by 61.6% of respondents in 2000 and in 2018 these respondents changed to use intermittent irrigation practice. Only 9 respondents used intermittent irrigation practice in past and still continue this practice in present (Table 4.42).

Seventy five percent of respondents irrigated by communal system. Farmers made small irrigation channels by themselves when irrigation channel was undeveloped in the past. The same percentages of respondents used national irrigation system due to irrigation channel developed in some area by governmental support at present. Four quarter of the respondents irrigated from rainfall in past and still irrigated rainfall in present because irrigation channel didn't develop in their rice field area (Table 4.43).

Changes of sources of water irrigation for wet season rice used by respondents were significantly varied according to group of water irrigation sources they used (χ^2=160, $p < 0.01$). In 2000, 120 persons of respondents used communal system for rice field irrigation and in 2018 they changed to use national irrigation system. Twenty five percent of persons of respondents irrigated by rainfall in both past and present (Table 4.44).

4.1.2.6 Fertilizer management

In 2000, only 2.5% of respondents did not use organic fertilizer (cow dung manure), whereas 57.5% of respondents used same amount of organic fertilizer used at present. In estimation 17.5% of respondents applied more than amount at present and 22.5% used less than the present amount. In 2018, almost all of the respondents (96.9%) applied organic fertilizer (cow dung manure) and only 3.1% did not apply organic fertilizer because cattle were few at present using machine instead of cattle (Table 4.45).

Table 4.40 Changes of spatial arrangement of transplanting for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Spatial arrangement (2000)	Respondents (n=160)		
	Spatial arrangement (2018)		
	Random	Row planting	Erratic
Random	83 (55.0)	67 (44.4)	1 (0.7)
Row planting	1 (11.1)	8 (88.9)	0 (0.0)
χ^2	6.7*		

Figures in the parentheses are percentages.
* = significance at 5% level

Table 4.41 Water management for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Water management	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Permanent flooding	151	94.4	58	36.3
Intermittent irrigation	9	5.6	102	63.8
Total	160	100.0	160	100.0

Table 4.42 Changes of water management for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Water management (2000)	Respondents (n=160)	
	Water management (2018)	
	Permanent flooding	Intermittent irrigation
Permanent flooding	58 (38.4)	93 (61.6)
Intermittent irrigation	0 (0.0)	9 (100.0)
χ^2	5.4*	

Figures in the parentheses are percentages.

* = significance at 5% level

Table 4.43 Sources of water irrigation for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

Sources	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Irrigation communal system	120	75.0	-	-
Irrigation national system	-	-	120	75.0
Rainfall	40	25.0	40	25.0
Total	160	100.0	160	100.0

Table 4.44 Changes of sources of water irrigation for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

Sources (2000)	Respondents (n=160)	
	Sources (2018)	
	Irrigation national system	Rainfall
Irrigation communal system	120 (100.0)	0 (0.0)
Rainfall	0 (0.0)	40 (100.0)
χ^2	160.0**	

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.45 Organic fertilizer application for wet season rice used by respondents in 2000 in Meiktila Township

Organic fertilizer application	Respondents (n=160)	
	Frequency	Percentage
2000		
Less than present amount	36	22.5
More than present amount	28	17.5
Same amount as present	92	57.5
None	4	2.5
Total	160	100.0
2018		
Yes	155	96.9
No	5	3.1
Total	160	100.0

The percentages of respondents (58.8%) used chemical fertilizers in both past and present. Forty percent of respondents did not apply chemical fertilizer in past and in present these respondents changed to be applied (Table 4.46). For wet season rice, average nitrogen fertilizers application was 71.7 kg per ha in 2018. Within the range of (1-50) kg per ha applied by 28.1% of respondents in present, (50.1-100) kg per ha used by 49.4% and 21.3% of respondents used 100.1 to 150 kg per ha in present. In 2018, only 0.6% of respondents were applied 150.1 to 200 kg per ha and the same percentages of respondents used more than 200 kg per ha of nitrogen fertilizer (Table 4.47). In 2000, the estimation of nitrogen fertilizer usage was found as used same amount of nitrogen fertilizer (urea) 9.4% of respondents, more than present 3.8% of respondents and less then present 45%. Forty two percent of respondents did not use nitrogen fertilizer (Table 4.48).

Thirty one percentages of respondents had no phosphorus fertilizer application for wet season rice in present. In 2018, 13.1%, 20.6% and 28.8% of respondents applied phosphorus fertilizer within the range of (0.8-4), (4.1-8) and (8.1-12) kg per ha, respectively. And also 1.9% of respondents used 12.1 to 16 kg per ha and the similar percentage used 16.1 to 20 kg per ha. Only 3.1% of respondents applied more than 20 kg per ha in present (Table 4.49). In 2000, the majority of respondents (95%) had no phosphorus fertilizer application and 3.8% of them used same amount of phosphorus fertilizer as present. Similarity of small percentages (0.6%) of respondents applied phosphorus fertilizer more than present and less than present amount (Table 4.50).

For wet season rice, average application of potassium fertilizers were 8.3 kg per ha in present. The percentages of respondents (33.1%) did not use potassium fertilizer in present. Four quarter of respondents applied 1 to 1.8 kg per ha and 35.6% of them used 8.1 to 16 kg per ha in present. Within the range of (16.1-24), (24.1-32) and (32.1-40) kg per ha were applied by 1.9%, 2.5% and 1.9% of respondents, respectively (Table 4.51). In 2000, most of the respondents (96.3%) did not use potassium fertilizer and 3.1% used same amount as present and then only 0.6% used less than present (Table 4.52). In study area, all respondents had no other type of fertilizer application for wet season rice between 2000 and 2018.

Twenty five percent of respondents were practiced one-split fertilizer application in 2000 and in 2018 decreased to 3.1%. Two-split application practiced by 25.6% of respondents in past and increased to 56.3% in present. Eight percent of respondents used three-split fertilizer application in past and in present increased to 38.1%. No fertilizer application was practiced by 41.3% of respondents in past. Only 2.5% of respondents practiced four-split fertilizer application in present (Table 4.53).

Table 4.46 Chemical fertilizer application for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

Chemical fertilizer application	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
No	66	41.3	-	-
Yes	94	58.8	160	100.0
Total	160	100.0	160	100.0

Table 4.47 Nitrogen fertilizer application for wet season rice used by respondents at 2018 in Meiktila Township

Nitrogen fertilizer application (kg/ha)	Respondents (n=160)	
	2018	
	Frequency	Percentage
1-50	45	28.1
50.1-100	79	49.4
100.1-150	34	21.3
150.1-200	1	0.6
over 200	1	0.6
Total	160	100.0
Mean	71.7	
Minimum	3.8	
Maximum	201.3	

Table 4.48 Nitrogen fertilizer application for wet season rice used by respondents in 2000 in Meiktila Township

Nitrogen fertilizer application	Respondents (n=160)	
	2000	
	Frequency	Percentage
Less than present amount	72	45.0
More than present amount	6	3.8
Same amount as present	15	9.4
None	67	41.9
Total	160	100.0

Table 4.49 Phosphorus fertilizer application for wet season rice used by respondents at 2018 in Meiktila Township

Phosphorus fertilizer application (kg/ha)	Respondents (n=160)	
	2018	
	Frequency	Percentage
0	49	30.6
0.8-4	21	13.1
4.1-8	33	20.6
8.1-12	46	28.8
12.1-16	3	1.9
16.1-20	3	1.9
over 20	5	3.1
Total	160	100.0
Mean	5.6	
Minimum	0.0	
Maximum	57.5	

Table 4.50 Phosphorus fertilizer application for wet season rice used by respondents in 2000 in Meiktila Township

Phosphorus fertilizer application	Respondents (n=160)	
	2000	
	Frequency	Percentage
Less than present	1	0.6
More than present	1	0.6
Same amount as present	6	3.8
None	152	95.0
Total	160	100.0

Table 4.51 Potassium fertilizer application for wet season rice used by respondents in 2018 in Meiktila Township

Potassium fertilizer application (kg/ha)	Respondents (n=160)	
	2018	
	Frequency	Percentage
0	53	33.1
1-8	40	25.0
8.1-16	57	35.6
16.1-24	3	1.9
24.1-32	4	2.5
32.1-40	3	1.9
Total	160	100.0
Mean	8.3	
Minimum	0.0	
Maximum	32.1	

Table 4.52 Potassium fertilizer application for wet season rice used by respondents in 2000 in Meiktila Township

Potassium fertilizer application	Respondents (n=160)	
	2000	
	Frequency	Percentage
Less than present amount	1	0.6
Same amount as present	5	3.1
None	154	96.3
Total	160	100.0

Table 4.53 Frequency of fertilizer application for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Frequency of fertilizer application	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
One-split	40	25.0	5	3.1
Two-split	41	25.6	90	56.3
Three-split	13	8.1	61	38.1
Four-split	-	-	4	2.5
Five-split	-	-	-	-
No fertilizer application	66	41.3	-	-
Total	160	100.0	160	100.0

Changes of frequency of fertilizer application for wet season rice used by respondents were significantly varied according to group of frequency of fertilizer application they practiced (χ^2=25.7, $p < 0.05$). In 2000, the respondents who used one-split application in 2018 changed to use two-split application (57.5%), three-split (35%), four-split application (2.5%) and after that five-split fertilizer application (2.5%), respectively. Thirty nine percent of respondents practiced two-split application in past and in present changed to practice three-split application. Three-split fertilizer application was practiced by 7.7% of respondents in past whereas the same respondents used two-split method of fertilizer application in present. In 2000, 6.1% of respondents had no fertilizer application and these respondents became practicing one-split application. Moreover, 62.1% of them used two-split and 28.8% used three-split application in present (Table 4.54).

For fertilizer application of wet season rice, average family labours were 1 and 2 persons per ha in past and present, respectively. Changing family labours for fertilizer application for wet season rice used by respondents during 20 years were significantly different ($t = -8.3$, $p < 0.01$). In 2000, 47.5% of respondents did not use family labours for fertilizer application and decreased to 14.4% in 2018. For application, 11.9%, 33.1% and 1.3% of respondents used within the range of (1-2), (3-4) and (5-6) persons per ha in past and in present these respondents increased to 23.8%, 51.9% and 1.9%, respectively. More than 6 persons per ha of family labours were used by 1.9% of respondents in present and this percentage increased to 3.1% in present (Table 4.55).

Changes of family labours for fertilizer application for wet season rice used by respondents were significantly varied according to group of family labours for fertilizer application they used (χ^2=308, $p < 0.01$). The respondents who did not use family labours in past changed to use less than one person per ha (6%) in present, 1 to 2 persons per ha (19.7%) and 3 to 4 persons per ha (42.1%) in present. Fifty seven percent of respondents used less than one person per hectare in past but in present they used 1 to 2 persons per ha and 14.3% of them used 3 to 4 persons per ha. Majorities of the respondents who used family labours (89.5%), (92.5%) 1-2 and 3-4 persons per ha in 2000 did not change their labours usages in 2018. There was no change of family labours usages of respondents who used 5 to 6 and more than 6 persons per hectare (Table 4.56).

Table 4.54 Changes of frequency of fertilizer application for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Frequency of fertilizer application (2000)	Respondents (n=160)			
	Frequency of fertilizer application (2018)			
	One-split	Two-split	Three-split	Four-split
One-split	1 (2.5)	23 (57.5)	14 (35.0)	2 (5.0)
Two-split	0 (0.0)	25 (61.0)	16 (39.0)	0 (0.0)
Three-split	0 (0.0)	1 (7.7)	12 (92.3)	0 (0.0)
No fertilizer application	4 (6.1)	41 (62.1)	19 (28.8)	2 (3.0)
χ^2	25.7*			

Figures in the parentheses are percentages.

* = significance at 5% level

Table 4.55 Family labours for fertilizer application for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	76	47.5	23	14.4
<1	7	4.4	8	5.0
1-2	19	11.9	38	23.8
3-4	53	33.1	83	51.9
5-6	2	1.3	3	1.9
over 6	3	1.9	5	3.1
Total	160	100.0	160	100.0
Mean	1.0		2.0	
Minimum	0.0		0.0	
Maximum	5.0		5.0	
t value	-8.3**			

** = significance at 1% level

Table 4.56 Changes of family labours for fertilizer application in wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (2000) (person/ha)	Respondents (n=160)					
	No. of family labours (2018) (person/ha)					
	0	<1	1-2	3-4	5-6	over 6
0	22 (28.9)	5 (6.6)	15 (19.7)	32 (42.1)	1 (1.3)	1 (1.3)
<1	0 (0.0)	2(28.6)	4 (57.1)	1 (14.3)	0 (0.0)	0 (0.0)
1-2	0 (0.0)	1 (5.3)	17 (89.5)	1 (5.3)	0 (0.0)	0 (0.0)
3-4	1 (1.9)	0 (0.0)	2 (3.8)	49 (92.5)	0 (0.0)	1 (1.9)
5-6	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)
over 6	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (100.0)
χ^2	308**					

Figures in the parentheses are percentages.
** = significance at 1% level

For fertilizer application of wet season rice, average hired labours were 1 and 2 persons per ha in past and present, respectively. Changing hired labours for fertilizer application for wet season rice used by respondents during 20 years were significantly different ($t = -4.2$, $p < 0.01$). Most of the respondents (91.9%) who did not hired labours in past decreased to 80% in present. In 2000, within the range of 1 to 2 persons per ha hired by few respondents (0.6% and 1.9%) slightly increased to 13% and 6.9%, respectively in 2018. Within the range of (3-4) persons per ha were hired by 5.6% of respondents in past and increased to 10% in present. A few percentages of respondents (0.6%) who used hired labours more than 4 persons per ha in past increased to 1.3% in present (Table 4.57).

Changes of hired labours for fertilizer application for wet season rice used by respondents were significantly varied according to group of hired labours for fertilizer application they used ($\chi^2=188.6$, $p < 0.01$). Among the respondents who had no hired labours in past 2%, 4.8% and 5.4% of them changed to use less than one person per ha, 1 to 2 persons per ha, 3 to 4 persons per ha, respectively in present. Within the range of (3-4) persons per ha were used by 11.1% of respondents in past and changed to use 1 to 2 persons per ha in present. It can be assumed that significantly change in hired labours usage in 2018 was due to increase use of labours by some respondents who did not hire labours in the past (Table 4.58).

4.1.2.7 Weed management

The percentage of respondents (10.6%) who practiced manual weeding in past increased to 42.3% in present. Eighty nine percent of respondents did not control weed in 2000 and these respondents decreased to 56.3% in 2018. Only 1.3% practiced weed management by using chemical (herbicide) in present (Table 4.59).

Changes of weed management for wet season rice practiced by respondents were significantly varied according to group of weed management they practiced ($\chi^2=16.2$, $p < 0.01$). In 2000, 11.8% of respondents practiced weeding and in 2018 these respondents did not operate weeding. Thirty seven percentages of respondents who did not operate weeding in past changed to practice manual weeding in present and only 1.4% of them used chemical for weeding (Table 4.60).

Table 4.57 Hired labours for fertilizer application for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	147	91.9	128	80.0
<1	1	0.6	3	1.9
1-2	2	1.3	11	6.9
3-4	9	5.6	16	10.0
over 4	1	0.6	2	1.3
Total	160	100.0	160	100.0
Mean	1.0		2.0	
Minimum	0.0		0.0	
Maximum	5.0		5.0	
t value	-4.2**			

** = significance at 1% level

Table 4.58 Changes of hired labours for fertilizer application for wet season used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (2000) (person/ha)	Respondents (n=160)				
	No. of hired labours (2018) (person/ha)				
	0	<1	1-2	3-4	over 4
0	128 (87.1)	3 (2.0)	7 (4.8)	8 (5.4)	1 (0.7)
<1	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)	0 (0.0)
1-2	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)
3-4	0 (0.0)	0 (0.0)	1 (11.1)	8 (88.9)	0 (0.0)
over 4	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)
χ^2	188.6**				

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.59 Weed management for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Weed management	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Chemical	-	-	2	1.3
Manual	17	10.6	68	42.5
None	143	89.4	90	56.3
Total	160	100.0	160	100.0

Table 4.60 Changes of weed management for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Weed management (2000)	Respondents (n=160)		
	Weed management (2018)		
	Chemical	Manual	None
Manual	0 (0.0)	15 (88.2)	2 (11.8)
None	2 (1.4)	53 (37.1)	88 (61.5)
χ^2		16.2**	

Figures in the parentheses are percentages.

** = significance at 1% level

For weeding of wet season rice, average family labours were 1 and 2 person per ha in past and present, respectively. During 20 years, family labours for weeding of the respondents were significantly changed ($t = -4.1$, $p < 0.01$). The higher percentage (91.9%) of respondents did not use family labours in past and these respondents decreased to 75.6% in present. In 2000, 4.4% of respondents used 1 to 4 persons per ha and 2.5% used 5 to 8 persons per ha however in 2018 these respondents were increased 13.1% and 8.1%, respectively. More than 8 family labours per ha was used by very few respondents and their changes were found to be negligible during 20 years (Table 4.61).

Changes of family labours for weeding of wet season rice used by respondents were significantly varied according to group of family labours for weeding they used ($\chi^2=198.8$, $p < 0.01$). The percentages of respondents (80.3%) who did not use family labours in past were not changed their family labours used in present. however, 10.9%, 6.1% and 2% of them used (1-4) persons per ha, (5 to 8) persons per ha and (13 to 16) persons per ha in present, respectively. In 2000, 28.6% of respondents used 1 to 4 persons per ha changed to use 5 to 8 persons per ha in 2018. Fifty percent of respondents used within the range of (5-8) persons per ha in past and these respondents did not use family labours at present (Table 4.62).

For weeding of wet season rice, average hired labours were 1 and 3 persons per ha in past and present, respectively. During 20 years, hired labours for weeding of the respondents were significantly changed ($t = -5.5$, $p < 0.01$). Almost all of the respondents (95.6%) who did not hire labours in past were decreased to 75% in present. Two percent of respondents hired 1 to 5 persons per ha in past and increased to 7.5% at present. In 2000, 1.3% of respondents used 11 to 15 persons per ha and the same percent used 21 to 25 persons per ha, in 2018 however they were increased to 7.5% and 4.4% respectively. Few respondents hired 6 to 10 persons per ha and (16-20) persons per ha for manual weeding (Table 4.63).

Changes of hired labours for weeding of wet season rice used by respondents were significantly varied according to group of hired labours for weeding they used ($\chi^2=106.7$, $p < 0.01$). Seventy eight percent of respondents had no hired labours for weeding in both past and present. Among the rests of those respondents few percentages of them changed to use hired labours in varied numbers in 2018. The range of hired labours (1-5), (11-15) and (21-25) used by respondents were not change in both past and present (Table 4.64).

Table 4.61 Family labours for weeding for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	147	91.9	121	75.6
<1	-	-	1	0.6
1-4	7	4.4	21	13.1
5-8	4	2.5	13	8.1
9-12	1	0.6	1	0.6
13-16	-	-	3	1.9
over 16	1	0.6	-	-
Total	160	100.0	160	100.0
Mean	1.0		2.0	
Minimum	0.0		0.0	
Maximum	18.0		13.0	
t value	-4.1**			

** = significance at 1% level

Table 4.62 Changes of family labours for weeding for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (2000) (person/ha)	Respondents (n=160)					
	No. of family labours (2018) (person/ha)					
	0	<1	1-4	5-8	9-12	13-16
0	118 (80.3)	1 (0.7)	16 (10.9)	9 (6.1)	0 (0.0)	3 (2.0)
1-4	0 (0.0)	0 (0.0)	5 (71.4)	2 (28.6)	0 (0.0)	0 (0.0)
5-8	2 (50.0)	0 (0.0)	0 (0.0)	2 (50.0)	0 (0.0)	0 (0.0)
9-12	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)
over 16	1 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
χ^2	198.8**					

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.63 Hired labours for weeding for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	153	95.6	120	75.0
1-5	3	1.9	12	7.5
6-10	-	-	6	3.8
11-15	2	1.3	12	7.5
16-20	-	-	3	1.9
21-25	2	1.3	7	4.4
Total	160	100.0	160	100.0
Mean	1.0		3.0	
Minimum	0.0		0.0	
Maximum	25.0		25.0	
t value	-5.5**			

** = significance at 1% level

Table 4.64 Changes of hired labours for weeding for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (2000) (person/ha)	Respondents (n=160)					
	No. of hired labours (2018) (person/ha)					
	0	1-5	6-10	11-15	16-20	21-25
0	120 (78.4)	9 (5.9)	6 (3.9)	10 (6.5)	3 (2.0)	5 (3.3)
1-5	0 (0.0)	3 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
11-15	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)	0 (0.0)	0 (0.0)
21-25	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (100.0)
χ^2	106.7**					

Figures in the parentheses are percentages.

** = significance at 1% level

One time of weeding practiced by 7.5% of respondents in past and these respondents increased to 25% in present. In 2000, 2.5% of respondents done two times of weeding also increased to 16.3% in 2018. Only 0.6% used three times of weeding in past. According to the awareness on effects of weed the respondents increased to 2.5% in present. The highest percentage of respondents (89.4%) who did not operate weed control in past decreased 56.3% at present (Table 4.65).

Changes of frequency of weeding for wet season rice practiced by respondents were significantly varied according to group of frequency of weeding they practiced (χ^2=106.7, $p < 0.01$). Twenty five percent of the respondents practiced one time weeding in past and in present these respondents practiced two times weeding and then 16.7% of them did not control weed. According to chi-square analysis, the apparent changes were found in no weed control group. In 2000, 23.1% of respondents in this group who had no weeding changed to practice one time of weeding in 2018 and 13.3% of them used two times of weeding. However, 2.1% used three times of weeding and 61.5% still continued no weeding (Table 4.66).

4.1.2.8 Pest, disease and bird control

In 2000, only 1.9% of respondents used chemical (pesticide) to control pests and diseases and these respondents significantly increased to 66.3% in 2018. Ninety eight percent of respondents did not control pests and diseases in past and decreased to 33.8% in present. In 2000, all respondents did not control birds because their field area had no serious damage of birds and these respondents decreased to 94.4% in 2018. Birds control was practiced by 5.6% of respondents in present (Table 4.67).

4.1.2.9 Harvesting and threshing

For wet season rice, although all respondents harvested rice by manual in 2000, 68.8% of them used manual harvesting and 31% of respondents used combined harvester in 2018 (Table 4.68). For wet season rice harvesting, average family labours were 2 and 1 person per ha in past and present, respectively. Changing family labours for wet season rice harvesting used by respondents during 20 years were significantly different ($t = 1.6$, $p < 0.05$). In 2000, 72.5% of respondents who did not use family labours in past increased to 75.6% in 2018. Within the range of (1-6) persons per ha was used by 21.3% of respondents in past and decreased to 19.4% in present. Few percentages of respondents respectively used more than 6 persons per ha and there were little changes between 2000 and 2018 (Table 4.69).

Table 4.65 Frequency of weeding for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Frequency of weeding	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
One time	12	7.5	40	25.0
Two times	4	2.5	26	16.3
Three times	1	0.6	4	2.5
None	143	89.4	90	56.3
Total	160	100.0	160	100.0

Table 4.66 Changes of frequency of weeding for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Frequency of weeding (2000)	Respondents (n=160)			
	Frequency of weeding (2018)			
	One time	Two times	Three times	None
One time	7 (58.3)	3 (25.0)	0 (0.0)	2 (16.7)
Two times	0 (0.0)	4 (100.0)	0 (0.0)	0 (0.0)
Three times	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)
None	33 (23.1)	19 (13.3)	3 (2.1)	88 (61.5)
χ^2	70.9**			

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.67 Pest, disease and bird control of respondents between 2000 and 2018 in Meiktila Township

Control measure	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Pest and disease control				
Chemical	3	1.9	106	66.3
None	157	98.1	54	33.8
Total	160	100.0	160	100.0
Birds control				
No	160	100.0	151	94.4
Yes	-	-	9	5.6
Total	160	100.0	160	100.0

Table 4.68 Harvesting methods for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Harvesting method	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Combined harvester	-	-	50	31.3
Manual	160	100.0	110	68.8
Total	160	100.0	160	100.0

Table 4.69 Family labours for harvesting of wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	116	72.5	121	75.6
1-6	34	21.3	31	19.4
7-12	5	3.1	6	3.8
13-18	2	1.3	1	0.6
over 18	3	1.9	1	0.6
Total	160	100.0	160	100.0
Mean	2.0		1.0	
Minimum	0.0		0.0	
Maximum	20.0		20.0	
t value	1.6*			

* = significance at 5% level

Changes of family labours for harvesting for wet season rice used by respondents were significantly varied according to group of family labours they used (χ^2=249.8, $p < 0.01$). The percentages of respondents (4.3%) who did not use family labours in past changed to use within the range of (1-6) persons per ha and 1.7% of them used 7 to 12 persons per ha in present. Three percent of respondents who used family labours within the range of (1-6) persons per ha in past used 7 to 12 persons per ha and 29.4% of them did not use family labours in 2018. In 2000, 20% of respondents used 7 to 12 persons per ha and in 2018 uses of family labours were changed to the range of (1-6) persons per ha after that 20% of them were not used family labours. Fifty percent of respondents used 13 to 18 persons per ha in past and in present changed to use 1 to 6 persons per ha. Over 18 persons per ha were used by 33.3% of respondents in past and in present these respondents changed to use 1 to 6 persons per ha and then 33.3% of them did not use family labours at present (Table 4.70).

For wet season rice harvesting, average hired labours were 21 and 16 persons per ha in past and present, respectively. Changing hired labours for wet season rice harvesting used by respondents during 20 years were significantly different ($t = 4.4$, $p < 0.01$). Four percent of respondents who did not hire labours in past and these respondents increased to 32.5% in present. In 2000, hired labours uses were 1 to 10 persons per ha by 6.3%, 11 to 20 persons per ha by 38.1% and 21 to 30 persons per ha by 43.1%, while the respondents decreased to 1.9%, 25% and 29.4% respectively, in 2018. The percentage of respondents (8.1%) who used 31 to 40 persons per ha in past increased to 11.3% in present (Table 4.71).

Changes of hired labours for harvesting for wet season rice used by respondents were significantly varied according to group of hired labours they used (χ^2=140.7, $p < 0.01$). Substantial decreased number of hired labours was found in 2018. Some respondents who used different numbers of hired labours in 2000 had changed not to hire some labours. It was found in those respondents who hired (10-20) persons per ha in 2000, 14.8% of them did not hire labours in 2018. More than half of respondents (53.6%) who used (20-30) persons per ha and 30.8% who used more than 30 persons per ha did not hire labours in 2018. The same number of labours were still hired respectively by 20% of respondents who had (1-10) persons per ha, 50.8% who used (11-20) persons per ha, 34.4% who hired (21-30) persons per ha and 69.2% who used more than 30 persons per ha in 2018 (Table 4.72).

Table 4.70 Changes of family labours for harvesting for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (2000) (person/ha)	Respondents (n=160)				
	No. of family labours (2018) (person/ha)				
	0	1-6	7-12	13-18	over 18
0	109 (94.0)	5 (4.3)	2 (1.7)	0 (0.0)	0 (0.0)
1-6	10 (29.4)	23 (67.6)	1 (2.9)	0 (0.0)	0 (0.0)
7-12	1 (20.0)	1 (20.0)	3 (60.0)	0 (0.0)	0 (0.0)
13-18	0 (0.0)	1 (50.0)	0 (0.0)	1 (50.0)	0 (0.0)
over 18	1 (33.3)	1 (33.3)	0 (0.0)	0 (0.0)	1 (33.3)
χ^2	249.8**				

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.71 Hired labours for harvesting of wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	7	4.4	52	32.5
1-10	10	6.3	3	1.9
11-20	61	38.1	40	25.0
21-30	69	43.1	47	29.4
31-40	13	8.1	18	11.3
Total	160	100.0	160	100.0
Mean	21.0		16.0	
Minimum	0.0		0.0	
Maximum	40.0		40.0	
t value	4.4**			

** = significance at 1% level

Table 4.72 Changes of hired labours for harvesting for wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (person/ha) (2000)	Respondents (n=160)				
	No. of hired labours (person/ha) (2018)				
	0	1-10	11-20	21-30	31-40
0	2 (28.6)	1 (14.3)	2 (28.6)	1 (14.3)	1 (14.3)
1-10	0 (0.0)	2 (20.0)	7 (70.0)	1 (10.0)	0 (0.0)
11-20	9 (14.8)	0 (0.0)	31 (50.8)	19 (31.1)	2 (3.3)
21-30	37 (53.6)	0 (0.0)	0 (0.0)	26 (37.7)	6 (8.7)
31-40	4 (30.8)	0 (0.0)	0 (0.0)	0 (0.0)	9 (69.2)
χ^2	140.7**				

Figures in the parentheses are percentages.
** = significance at 1% level

For wet season rice, half of the respondents threshed by animal in past and decreased to 1.3% in present. In 2000, 41.9% of respondents threshed by manual and in 2018 decreased to 8.8%. Eight percent of respondents used thresher in past and increased to 58.1% in present. Combined harvester was used by 31.9% of respondents in present (Table 4.73). Changes of threshing method used by respondents were significantly varied according to group of threshing method they practiced (χ^2=19.3, $p < 0.05$). Forty percent of respondents threshed by animal in past and in present these respondents changed to use combined harvester, 2.55% of them practiced manual threshing method and 55% of them used thresher. In 2000, 19.4% of respondents practiced manual threshing and in 2018 changed to thresh by combined harvester and 62.7% of them practiced by thresher. Forty six percent of respondents threshed by thresher in past and in present used combine harvester (Table 4.74).

For wet season rice threshing, average family labours were 2 and 1 person per ha in past and present, respectively. Changing family labours for wet season rice threshing used by respondents during 20 years were significantly different ($t = 5.1$, $p < 0.01$). The higher percentage (71.9%) of respondents did not use family labours in past and increased to 93.8% in present. The percentage of respondents (11.3%) who used 1 to 3 persons per ha in past decreased to 1.3% in present. Within the range of (4-6) and (7-9) persons per ha were used by 10% and 4.4% of respondents in past and in present decreased to 2.5% and 1.3%, respectively. Only 1.3% used 10 to 12 persons per ha and the same percent used more than 12 persons per ha in 2000 and in 2018 these respondents decreased to 0.6% and 0.6%, respectively (Table 4.75).

Changes of family labours for threshing of wet season rice used by respondents were significantly varied according to group of family labours they used (χ^2=150.9, $p < 0.01$). Eighty three percent of respondents used family labours within the range of (1-3) persons per ha in past and in present these respondents did not use family labours and 5.6% of them used 7 to 9 persons per ha. In 2000, 81.3% of respondents who used (4-6) persons per ha did not use family labours in 2018. Within the range of (7-9) persons per ha were used by 14.3% in past, in present changed to use 10 to 12 persons per ha and 71.4% of them did not use family labours. Two respondents used 10 to 12 persons per ha in past and in present they did not use. Only one respondent used more than 12 persons per ha in past and in present did not use family labours (Table 4.76).

Table 4.73 Threshing method practiced by respondents between 2000 and 2018 in Meiktila Township

Threshing method	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Animal	80	50.0	2	1.3
Combined harvester	-	-	51	31.9
Manual	67	41.9	14	8.8
Thresher	13	8.1	93	58.1
Total	160	100.0	160	100.0

Table 4.74 Changes of threshing method for wet season rice practiced by respondents between 2000 and 2018 in Meiktila Township

Threshing method (2000)	Respondents (n=160)			
	Threshing method (2018)			
	Animal	Combined harvester	Manual	Thresher
Animal	2 (2.5)	32 (40.0)	2 (2.5)	44 (55.0)
Manual	0 (0.0)	13 (19.4)	12 (17.9)	42 (62.7)
Thresher	0 (0.0)	6 (46.2)	0 (0.0)	7 (53.8)
χ^2	19.3*			

Figures in the parentheses are percentages.

* = significance at 5% level

Table 4.75 Family labours for threshing of wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	115	71.9	150	93.8
1-3	18	11.3	2	1.3
4-6	16	10.0	4	2.5
7-9	7	4.4	2	1.3
10-12	2	1.3	1	0.6
over 12	2	1.3	1	0.6
Total	160	100.0	160	100.0
Mean	2.0		1.0	
Minimum	0.0		0.0	
Maximum	18.0		13.0	
t value	5.1**			

** = significance at 1% level

Table 4.76 Changes of family labours for threshing of wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of family labours (person/ha) (2000)	Respondents (n=160)					
	No. of family labours (person/ha) (2018)					
	0	1-3	4-6	6-9	10-12	over 12
0	114 (99.1)	0 (0.0)	1 (0.9)	0 (0.0)	0 (0.0)	0 (0.0)
1-3	15 (83.3)	2 (11.1)	0 (0.0)	1 (5.6)	0 (0.0)	0 (0.0)
4-6	13 (81.3)	0 (0.0)	3 (18.8)	0 (0.0)	0 (0.0)	0 (0.0)
7-9	5 (71.4)	0 (0.0)	0 (0.0)	1 (14.3)	1 (14.3)	0 (0.0)
10-12	2 (100.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
over 12	1 (50.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)
χ^2	150.9**					

Figures in the parentheses are percentages.

** = significance at 1% level

For wet season rice threshing, average hired labours were 3 and 1 person per ha in past and present, respectively. Changing hired labours for wet season rice threshing used by respondents during 20 years were significantly different ($t = 5.6$, $p < 0.01$). The majority of respondents (75%) who didn't hire labours in past increased to 95.6% in present. Only 3.8% hired labours less than one person per ha in past. Within the range of (1-10), (11-20) and (21-30) persons per ha were hired by 10.6%, 8.1% and 2.5% of few respondents, respectively. In 2018, 3.1% of respondents hired 1 to 10 persons per ha and only 1.3% hired 11 to 20 persons per ha (Table 4.77).

Changes of hired labours for threshing of wet season rice used by respondents were significantly varied according to group of hired labours they used ($\chi^2=36.2$, $p < 0.01$). The highest percentage of respondents (98.3%) had no hired labours in both past and present and then 1.7% of them used 1 to 10 persons per ha in present. Six respondents hired less than one person per ha in past but they did not hire in present. Within the range of (1-10) and (11-20) persons per ha were hired by 82.4% and 84.6% of respondents in past, respectively and in present these respondents did not hire labours for threshing. Four respondents hired 21 to 30 persons per ha in past and these respondents did not use hired labours in present (Table 4.78).

4.1.3 Grain drying and straw management

In 2000, all respondents used straw to feed cattle and these respondents decreased to 98.8% in 2018. Only 1.3% of respondents used straw to incorporated into the soil in present (Table 4.79). The majority of respondents (92.5%) operated rice grain drying process before selling to market in past and slightly increased to 93.8% in present. Non drying process was done by 7.5% of respondents in past and in present decreased to 6.3% (Table 4.80).

For postharvest activities, 20.6% of respondents used hired labours in past and in present increased to 25%. Most of the respondents (79.4%) did not hire labours in past and decreased to 75% in present (Table 4.81). Changes of labours for postharvest activities used by respondents were significantly varied according to group of labours they used ($\chi^2=114.8$, $p < 0.01$). Three percent of respondents used hired labours in past but in present they did not use hired labours. The respondents (6.3%) who did not hire labours in past and in present changed to use hired labours (Table 4.82).

Table 4.77 Hired labours for threshing of wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	120	75.0	153	95.6
<1	6	3.8	-	-
1-10	17	10.6	5	3.1
11-20	13	8.1	2	1.3
21-30	4	2.5	-	-
Total	160	100.0	160	100.0
Mean	3.0		1.0	
Minimum	0.0		0.0	
Maximum	30.0		15.0	
t value	5.6**			

** = significance at 1% level

Table 4.78 Changes of hired labours for threshing of wet season rice used by respondents between 2000 and 2018 in Meiktila Township

No. of hired labours (person/ha) (2000)	Respondents (n=160)		
	No. of hired labours (person/ha) (2018)		
	0	1-10	11-20
0	118 (98.3)	2 (1.7)	0 (0.0)
<1	6 (100.0)	0 (0.0)	0 (0.0)
1-10	14 (82.4)	3 (17.6)	0 (0.0)
11-20	11 (84.6)	0 (0.0)	2 (15.4)
21-30	4 (100.0)	0 (0.0)	0 (0.0)
χ^2	36.2**		

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.79 Straw management of respondents between 2000 and 2018 in Meiktila Township

Straw management	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Incorporated into the soil	-	-	2	1.3
Feed to cattle	160	100.0	158	98.8
Total	160	100.0	160	100.0

Table 4.80 Rice grain drying before selling operated by respondents in 2000 and 2018 in Meiktila Township, 2018

Rice grain drying before selling	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Drying	148	92.5	150	93.8
Non drying	12	7.5	10	6.3
Total	160	100.0	160	100.0

Table 4.81 Labours for postharvest activities used by respondents between 2000 and 2018 in Meiktila Township

Labours for postharvest activities	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Hired	33	20.6	40	25.0
Non hired	127	79.4	120	75.0
Total	160	100.0	160	100.0

Table 4.82 Changes of labours for postharvest activities used by respondents between 2000 and 2018 in Meiktila Township

Labours for postharvest activities (2000)	Respondents (n=160)	
	Labours for postharvest activities (2018)	
	Hired	Non hired
Hired	32 (97.0)	1 (3.0)
Non hired	8 (6.3)	119 (93.7)
χ^2	114.8**	

Figures in the parentheses are percentages.

** = significance at 1% level

4.1.4 Rice yield, selling and keeping

For wet season, average rice yields were 2.3 and 3.3 tons in past and present, respectively. Changing rice yields for wet season of respondents during 20 years were significantly different ($t = -9.6$, $p < 0.01$). Forty one percent of respondents gained 0.1-2 tons per ha in past while 58.1% of respondents gained 2.1-4 tons per ha and in 2018 increased to 71.3%. Very few percentages of respondents (0.6%) obtained 4.1-6 tons per ha in past and increased to 15.6% in present. Few (1.3%) respondents got more than 6 tons per ha in present (Table 4.83).

Changes of rice yield for wet season of respondents were significantly varied according to group of rice yield they gained ($\chi^2=23.1$, $p < 0.01$). Seventy four percent of the respondents who gained the yield of 0.1-2 tons per ha in 2000 increased to 2.1-4 tons per ha and 4.5% of them got increased yield of 4.1-6 tons per ha in 2018. Among the respondents who gained their rice yield of 2.1-4 tons per ha in past and 22.6% of them increased to 4.1-6 tons per ha and then 2.2% of them increased to over 6 tons per ha in present. There was no change of rice yield of respondents who obtained 4.1-6 tons per ha (Table 4.84).

For wet season, average total amount of rice selling were 1.8 and 2.9 tons in past and present, respectively. Changing total amount of rice selling for wet season of respondents during 20 years were significantly different ($t = -5.0$, $p < 0.01$). More than half of the respondents (51.9%) had no rice selling in past and decreased to 40.6% in present. Thirty six percent of respondents sold 0.1-5 tons in both past and present. In 2000, 9.4% of respondents sold 5.1-10 tons and increased to 17.5% in present. Total amount of rice selling (10.1-15 tons) was sold by 1.9% in past and these respondents increased to 3.1% in present. A few percentages of respondents (1.3%) sold over 20 tons in past and in present increased to 1.9%. Only 1.3% of respondents sold 15.1-20 tons in present (Table 4.85).

Changes of total amount of rice selling for wet season of respondents were significantly varied according to group of total amount of rice they sold ($\chi^2=23.1$, $p < 0.01$). The respondents who did not sell in past, sold 0.1-5 tons in present. And also 6% of them sold 5.1-10 tons and 2.4% of them sold 10.1-15 tons in present. The respondents (29.8%) who sold 0.1-5 tons in past increased to sell 5.1-10 tons and 1.8% of them sold increased amount of 10.1-15 tons after that 3.5% of them did not sell rice in present. In 2000, 13.3% of respondents sold 5.1-10 tons in past and in present changed to sell 10.1-15 tons, however 46.7% of them sold decrease amount of 0.1-5 tons. Very few percent of respondents who sold more than 15 tons were found to be little changed (Table 4.86). Almost all of the respondents kept rice in past and decreased to 93.1% in present (Table 4.87).

Table 4.83 Rice yield for wet season of respondents between 2000 and 2018 in Meiktila Township

Rice yield (ton/ha)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0.1-2	66	41.3	19	11.9
2.1-4	93	58.1	114	71.3
4.1-6	1	0.6	25	15.6
over 6	-	-	2	1.3
Total	160	100.0	160	100.0
Mean	2.3		3.3	
Minimum	0.5		0.6	
Maximum	4.1		6.1	
t value	-9.6**			

**= significance at 1% level

Table 4.84 Changes of rice yield for wet season of respondents between 2000 and 2018 in Meiktila Township

Rice yield (ton/ha) (2000)	Respondents (n=160)			
	Rice yield (ton/ha) (2018)			
	0.1-2	2.1-4	4.1-6	over 6
0.1-2	14 (21.2)	49 (74.2)	3 (4.5)	0 (0.0)
2.1-4	5 (5.4)	65 (69.9)	21 (22.6)	2 (2.2)
4.1-6	0 (0.0)	0 (0.0)	1 (100.0)	0 (0.0)
χ^2	23.1**			

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.85 Total amount of rice selling for wet season of respondents between 2000 and 2018 in Meiktila Township

Total amount of rice selling (ton)	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
0	83	51.9	65	40.6
0.1-5	57	35.6	57	35.6
5.1-10	15	9.4	28	17.5
10.1-15	3	1.9	5	3.1
15.1-20	-	-	2	1.3
over 20	2	1.3	3	1.9
Total	160	100.0	160	100.0
Mean	1.8		2.9	
Minimum	0.0		0.0	
Maximum	21.0		27.7	
t value	-5.0**			

** = significance at 1% level

Table 4.86 Changes of total amount of rice selling for wet season of respondents between 2000 and 2018 in Meiktila Township

Total amount of rice selling (ton) (2000)	Respondents (n=160)					
	Total amount of rice selling (ton) (2018)					
	0	0.1-5	5.1-10	10.1-15	15.1-20	over 20
0	63 (75.9)	13 (15.7)	5 (6.0)	2 (2.4)	0 (0.0)	0 (0.0)
0.1-5	2 (3.5)	37 (64.9)	17 (29.8)	1 (1.8)	0 (0.0)	0 (0.0)
5.1-10	0 (0.0)	7 (46.7)	6 (40.0)	2 (13.3)	0 (0.0)	0 (0.0)
10.1-15	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (33.3)	2 (66.7)
over 20	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (50.0)	1 (50.0)
χ^2	259.6**					

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.87 Rice keeping in wet season by respondents between 2000 and 2018 in Meiktila Township

Rice keeping	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
No	7	4.4	11	6.9
Yes	153	95.6	149	93.1
Total	160	100.0	160	100.0

4.1.5 Cultural practices for dry season

4.1.5.1 Changes of Dry season rice cultivation

All of the respondents had no dry season rice in 2000 because of water insufficient and 30.6% of these respondents did not grow in 2018. Dry season rice was cultivated by 69.4% of respondents at 2018 (Table 4.88).

4.1.5.2 Seed selection

Improved varieties (Manawthukha) and hybrid varieties (Palaethwe) were used by 23.4% and 76.6% of respondents in 2018, respectively. In present, eighty three percent of respondents used certified seed and 17.1% used non certified seed for dry season. Medium and short duration varieties were grown by 76.6% and 23.4% of respondents in 2018 (Table 4.89).

In 2018, 79.3% of respondents chose varieties for the reason of high yield whereas 7.2%, 5.4% and 8.1% of respondents had chosen varieties due to the reasons of eating quality, short duration and better price, respectively (Table 4.90). In present, more than half of the respondents (69.4%) obtained variety information from extension agents and then 30.6% of respondents obtained from fellow farmers (Table 4.91).

4.1.5.3 Land preparation

Six percent of respondents done by one stroke of tillage operation, through 82% of respondents operated two strokes tillage and 11.7% of them operated three strokes tillage in 2018. Although nine percent of respondents did not practice leveling, 16.2% used machine for leveling and 74.8% of respondents done by draught power in 2018 (Table 4.92).

4.1.5.4 Rice establishment

In 2018, almost all of the respondents (98.2%) practiced transplanting method and only 1.8% of respondents used seed broadcasting method. In 2018, 64.9% of respondents transplanted 14 to 28 days old seedling and 34.2% of respondents transplanted when seedling ages were older than 28 days. Only 0.9% of respondents did not use transplanting method. Thirty six percent of respondents transplanted by random spatial arrangement in present and then 64% of respondents used structure (rows) arrangement (Table 4.93).

Table 4.88 Rice cultivation for dry season of respondents between 2000 and 2018 in Meiktila Township

Rice cultivation for dry season	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
No	160	100.0	49	30.6
Yes	-	-	111	69.4
Total	160	100.0	160	100.0

Table 4.89 Seed selection for dry season at 2018 in Meiktila Township

Seed selection	Respondents (n=111)	
	2018	
	Frequency	Percentage
Rice varieties		
Hybrid	26	23.4
Improved	85	76.6
Total	111	100.0
Seed types		
Certified	92	82.9
Non certified	19	17.1
Total	111	100.0
Duration of rice variety		
Medium	85	76.6
Short	26	23.4
Total	111	100.0

Table 4.90 Varietal preferences of respondents for dry season at 2018 in Meiktila Township

Varietal preferences	Respondents (n=111)	
	2018	
	Frequency	Percentage
Better price	9	8.1
Short duration	6	5.4
Eating quality	8	7.2
High yield	88	79.3
Total	111	100.0

Table 4.91 Sources of varietal information for dry season by respondents at 2018 in Meiktila Township

Sources of varietal information	Respondents (n=111)	
	2018	
	Frequency	Percentage
Extension agents	77	69.4
Fellow farmers	34	30.6
Total	111	100.0

Table 4.92 Land preparation in dry season practiced by respondents at 2018 in Meiktila Township

Items	Respondents (n=111)	
	2018	
	Frequency	Percentage
Tillage operation		
One stroke	7	6.3
Two strokes	91	82.0
Three strokes	13	11.7
Total	111	100.0
Land leveling		
Draught power	83	74.8
Mechanical	18	16.2
No leveling	10	9.0
Total	111	100.0

Table 4.93 Rice establishment in dry season practiced by respondents at 2018 in Meiktila Township

Items	Respondents (n=111)	
	2018	
	Frequency	Percentage
Establishment methods		
Broadcasting	2	1.8
Transplanting	109	98.2
Total	111	100.0
Seedling age (Days)		
14-28	72	64.9
Older than 28	38	34.2
Not transplanting	1	0.9
Total	111	100.0
Spatial arrangement		
Random	40	36.0
Structure (rows)	71	64.0
Total	111	100.0

For dry season rice establishment, average family labours was one person per hectare in 2018. Almost all of the respondents did not use family members in rice establishment, while 3.6% of respondents used 1 to 2 persons per hectare and also the same percentage of respondents used within the range of (3-4) persons per hectare, respectively (Table 4.94). For dry season rice establishment, average hired labours was 25 persons per hectare in present. Within the range of (31-40) persons per hectare were used by 12.6% of respondents and also 73.9% of them hired (21-30) persons per hectare whereas 10.8% used (11-20) persons per hectare and a few percentage (0.9%) of respondents hired 1 to 10 persons per hectare, respectively. About two percent of respondents did not use hired labours at 2018 (Table 4.95).

4.1.5.5 Water management

In 2018, 89.2% of respondents practiced intermittent irrigation due to easy to control irrigation and drainage of rice field. And then 10.8% of respondents practiced permanent flooding because their rice fields depended on rainfall water and not easy to irrigate and drainage (Table 4.96). All respondents (69.4%) irrigated by national system (government support) while their rice field areas were developed irrigation channel in present.

4.1.5.6 Fertilizer management

Eighty nine percent of respondents applied organic fertilizer and 10.8% did not apply in present. Chemical fertilizers were applied by all respondents in 2018. All respondents had no other fertilizers application in present (Table 4.97).

For dry season rice, average amount of nitrogen fertilizers application was 83.9 kilograms per hectare in present. Most of the respondents (46.8%) used within the range of (40.1-80) kilograms per hectare and 31.5% of respondents used 80.1 to 120 kilograms per hectare. Thirteen percents of respondents applied 120.1 to 160 kilograms per hectare and 1.8% of respondents used 160.1 to 200 kilograms per hectare. Very few percentages of respondents (0.9%) applied more than 200 kilograms per hectare (Table 4.98).

For dry season rice, average phosphorus fertilizers application was 6.6 kilograms per ha in 2018. Twenty fight percent of respondents had no phosphorus fertilizer application. In 2018, 9%, 20.7% and 33.3% of respondents were applied phosphorus fertilizer within the range of (1-4), (4.1-8) and (8.1-12) kilograms per ha, respectively. Moreover few respondents (3.6% to 45%) used (12.1 to 16), (16-20) and more than 20 kilograms per ha, respectively (Table 4.99).

Table 4.94 Family labours for rice establishment for dry season used by respondents at 2018 in Meiktila Township

No. of family labours (person/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
0	103	92.8
1-2	4	3.6
3-4	4	3.6
Total	111	100.0
Mean	1.0	
Minimum	0.0	
Maximum	3.0	

Table 4.95 Hired labours for rice establishment for dry season used by respondents at 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
0	2	1.8
1-10	1	0.9
11-20	12	10.8
21-30	82	73.9
31-40	14	12.6
Total	111	100.0
Mean	25.0	
Minimum	0.0	
Maximum	38.0	

Table 4.96 Water management for dry season rice practiced by respondents at 2018 in Meiktila Township

Water management	Respondents (n=111)	
	2018	
	Frequency	Percentage
Permanent flooding	12	10.8
Intermittent irrigation	99	89.2
Total	111	100.0

Table 4.97 Soil improvement practices for dry season rice used by respondents at 2018 in Meiktila Township

Soil improvement practices	Respondents (n=111)	
	2018	
	Frequency	Percentage
Organic fertilizer application		
No	12	10.8
Yes	99	89.2
Total	111	100.0
Chemical fertilizer application		
Yes	111	100.0
Total	111	100.0
Other fertilizer application		
None	111	100.0
Total	111	100.0

Table 4.98 Nitrogen fertilizer application for dry season rice used by respondents at 2018 in Meiktila Township

Nitrogen fertilizer application (kg/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
1-40	7	6.3
40.1-80	52	46.8
80.1-120	35	31.5
120.1-160	14	12.6
160.1-200	2	1.8
over 200	1	0.9
Total	111	100.0
Mean	83.9	
Minimum	14.4	
Maximum	201.3	

Table 4.99 Phosphorus fertilizer application for dry season rice used by respondents at 2018 in Meiktila Township

Phosphorus fertilizer application (kg/ha)	Respondents (n=160)	
	2018	
	Frequency	Percentage
0	28	25.2
1-4	10	9.0
4.1-8	23	20.7
8.1-12	37	33.3
12.1-16	4	3.6
16.1-20	4	3.6
over 20	5	4.5
Total	111	100.0
Mean	6.6	
Minimum	0.0	
Maximum	57.5	

For dry season rice, average application of potassium fertilizers was 9.6 kilograms per ha in present. The percentages of respondents (29.7%) did not use potassium fertilizer. And then 23.4% of respondents applied 1 to 10 kilograms per ha and 39.6% of them used 10.1 to 20 kilograms per ha. Only 2.7% and 4.5% of respondents used within the range of (20.1-30) and (30.1 to 40) kilograms per ha in 2018 (Table 4.100). Only 1.8% of respondents used one-split fertilizer application. Two-split and three-split fertilizer application were used by 46.8% and 48.6% of respondents, respectively. Only 2.7% of respondents used four-split application in 2018 (Table 4.101).

For fertilizer application of dry season rice, average family labours usage was 2 persons per ha in 2018. Seventeen percent of respondents did not use family labours and (9.9%) used within the range of (1-2) persons per ha and more than half of the respondents (68.5%) used 3 to 4 persons per ha. Within the range of (5-6) persons per ha was used by 4.5% of respondents (Table 4.102).

For fertilizer application of dry season rice, average hired labours was one person per ha in present. In 2018, 75.7% of respondents did not use hired labours and only 6.3% used hired labours within the range of (1-2) persons per ha. And also 16.2% of respondents hired 3 to 4 persons per ha. Only 1.8% of respondents hired 5 to 6 persons per ha in 2018 (Table 4.103).

4.1.5.7 Weed management

A few percentages of respondents (2.7%) used chemical for weeding and 53.2% of respondents practiced manual weeding. However, 44.1% of respondents had no weeding for dry season rice. One time of weeding practiced by 25.2% of respondents and 30.6% of respondents practiced two times weeding in 2018. Similarly 44.1% of respondents had no weeding control for dry season rice (Table 4.104).

For weeding of dry season rice, average family labours was one person per ha in present. Seventy percent of respondents did not use family labours and 16.2% used 1 to 4 persons per ha. Within the range of (5-8) persons per ha were used by 11.7% of respondents and few respondents (1.8%) used more than 8 persons per ha (Table 4.105).

For manual weeding of dry season, average hired labours was 4 persons per ha in present. More than half of the respondents (69.4%) did not hire labours in present. Five percent of respondents hired 1 to 6 persons per ha and 9.9% of respondents hired 7 to 12 persons per ha. Eleven percent of respondents hired 13 to 18 persons per ha. More than 18 persons per ha of hired labours were respectively used by few respondents within 1.8% (Table 4.106).

Table 4.100 Potassium fertilizer application for dry season rice used by respondents at 2018 in Meiktila Township

Potassium fertilizer application (kg/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
0	33	29.7
1-10	26	23.4
10.1-20	44	39.6
20.1-30	3	2.7
30.1-40	5	4.5
Total	111	100.0
Mean	9.6	
Minimum	0.0	
Maximum	32.1	

Table 4.101 Frequency of fertilizer application for dry season rice used by respondents at 2018 in Meiktila Township

Frequency of fertilizer application	Respondents (n=111)	
	2018	
	Frequency	Percentage
One-split	2	1.8
Two-split	52	46.8
Three-split	54	48.6
Four-split	3	2.7
Total	111	100.0

Table 4.102 Family labours for fertilizer application of dry season rice used by respondents at 2018 in Meiktila Township

No. of family labours (person/ha)	Respondents (n=160)	
	2018	
	Frequency	Percentage
0	19	17.1
1-2	11	9.9
3-4	76	68.5
5-6	5	4.5
Total	111	100.0
Mean	2.0	
Minimum	0.0	
Maximum	5.0	

Table 4.103 Hired labours for fertilizer application of dry season rice used by respondents at 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
0	84	75.7
1-2	7	6.3
3-4	18	16.2
5-6	2	1.8
Total	111	100.0
Mean	1.0	
Minimum	0.0	
Maximum	5.0	

Table 4.104 Weed management for dry season rice practiced by respondents at 2018 in Meiktila Township

Items	Respondents (n=111)	
	2018	
	Frequency	Percentage
Weed management		
Chemical	3	2.7
Manual	59	53.2
None	49	44.1
Total	111	100.0
Frequency of weeding		
One time	28	25.2
Two times	34	30.6
None	49	44.1
Total	111	100.0

Table 4.105 Family labors for weeding for dry season rice used by respondents at 2018 in Meiktila Township

No. of family labours (person/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
0	78	70.3
1-4	18	16.2
5-8	13	11.7
over 8	2	1.8
Total	111	100.0
Mean	1.0	
Minimum	0.0	
Maximum	13.0	

Table 4.106 Hired labors for weeding of dry season rice used by respondents at 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
0	77	69.4
1-6	6	5.4
7-12	11	9.9
13-18	12	10.8
19-24	2	1.8
25-30	2	1.8
over 30	1	0.9
Total	111	100.0
Mean	4.0	
Minimum	0.0	
Maximum	38.0	

4.1.5.8 Harvesting

Almost all of the respondents (95.5%) used combined harvester and 4.5% practiced manual harvesting for dry season rice at 2018 (Table 4.107). All respondents did not use family labours for harvesting of dry season rice in present. Average hired labours was one person per ha in present. Almost all of the respondents did not hire labours and 2.7% of respondents hired (1-10) persons per ha. Very few percentages (0.9%) of respondents hired (11-20) and (21-30) persons per ha at 2018 (Table 4.108).

4.1.6. Rice yield, selling and keeping

For dry season, average rice yield was 4.5 tons per ha in present. Within the range of (2.1-4) tons per ha were obtained by 37.8% of respondents and 57.7% of respondents obtained 4.1-6 tons per ha. Few respondents (4.5%) gained 6.1-8 tons per ha in present (Table 4.109).

For dry season, average total amount of rice selling was 5.1 tons per ha in present. In 2018, 14.4% of respondents could not sell their rice grain and 40.5% of respondents sold 0.1-4 tons. The relatively high percent of respondents (18.9%) sold 4.1-8 tons and 17.1% of respondents sold 8.1-12 tons. Within the high range of (12.1-16) and (16.1-20) tons were sold by 6.3% and 1.8% of respondents, respectively. Very few percent of respondents (0.9%) sold more than 20 tons (Table 4.110). More than half of the respondents (69.4%) kept rice for home consumption and seed. Thirty percent of respondents had no rice keeping (Table 4.111).

4.1.7 Market access for rice selling

In 2000, 48.8% of respondents sold rice to intermediary on farm and these respondents increased to 61.9% in 2018. Fifty one percent of respondents did not sell in past and in present 36.3% stayed not selling rice. In 2018, 0.6% and 1.3% of respondents sold to intermediary market and milling company, respectively (Table 4.112).

Changes of market access for rice selling of respondents were significantly varied according to group of access of market they sold (χ^2=71.8, $p < 0.01$). The respondents (1.3%) who sold rice to intermediary on farm in past changed to sell in milling company. The respondents (1.2%) who did not sell rice in past were sold to milling company in present and also 1.2% of them sold to intermediary market. The high number of respondents (30.5%) sold to intermediary on farm at present (Table 4.113).

Table 4.107 Harvesting method for dry season rice practiced by respondents at 2018 in Meiktila Township

Harvesting method	Respondents (n=111)	
	2018	
	Frequency	Percentage
Combined harvester	106	95.5
Manual	5	4.5
Total	111	100.0

Table 4.108 Hired labours for harvesting of dry season rice used by respondents at 2018 in Meiktila Township

No. of hired labours (person/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
0	106	95.5
1-10	3	2.7
11-20	1	0.9
21-30	1	0.9
Total	111	100.0
Mean	1.0	
Minimum	0.0	
Maximum	31.0	

Table 4.109 Rice yield for dry season of respondents at 2018 in Meiktila Township

Yield (ton/ha)	Respondents (n=111)	
	2018	
	Frequency	Percentage
2.1-4	42	37.8
4.1-6	64	57.7
6.1-8	5	4.5
Total	111	100.0
Mean	4.5	
Minimum	2.2	
Maximum	8.0	

Table 4.110 Total amount of rice selling for dry season of respondents at 2018 in Meiktila Township

Total amount of rice selling (ton)	Respondents (n=111)	
	2018	
	Frequency	Percentage
0	16	14.4
0.1-4	45	40.5
4.1-8	21	18.9
8.1-12	19	17.1
12.1-16	7	6.3
16.1-20	2	1.8
over 20	1	0.9
Total	111	100.0
Mean	5.1	
Minimum	0.0	
Maximum	22.5	

Table 4.111 Rice keeping of respondents for dry season at 2018 in Meiktila Township

Rice keeping	Respondents (n=111)	
	2018	
	Frequency	Percentage
No	34	30.6
Yes	77	69.4
Total	111	100.0

Table 4.112 Market access for rice selling of respondents in 2000 and 2018 in Meiktila Township, 2018

Market access for rice selling	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Intermediary on farm	78	48.8	99	61.9
Intermediary market	-	-	1	0.6
Milling company	-	-	2	1.3
Not selling	82	51.3	58	36.3
Total	160	100.0	160	100.0

Table 4.113 Changes of market access for rice selling of respondents between 2000 and 2018 in Meiktila Township

Market access for rice selling (2000)	Respondents (n=160)			
	Market access for rice selling (2018)			
	Intermediary on farm	Intermediary market	Milling company	Not selling
Intermediary on farm	74 (94.9)	0 (0.0)	1 (1.3)	3 (3.8)
Not selling	25 (30.5)	1 (1.2)	1 (1.2)	55 (67.1)
χ^2	71.8**			

Figures in the parentheses are percentages.

** = significance at 1% level

4.1.8 Most expensive activities in rice production

Among all rice production activities, rice establishment activity was more expensive for 96.3% of respondents in past and the percent decreased to 91.9% in present. In 2000, 3.8% of respondents expended more costs for harvesting and increased to 6.3% in 2018. Fertilizer costs was the third more expensive for 1.9% of respondents in present (Table 4.114). Changes of most expensive activities in rice production of respondents were significantly varied according to group of rice production activities they more expensed (χ^2=71.8, $p < 0.01$). The respondents who expended more costs for establishment in past 1.9% of them changed to fertilizer cost in present and also 3.2% of them changed to harvesting cost. Harvesting costs were more expensive for 16.7% of respondents in past and in present these respondents changed to rice establishment cost (Table 4.115).

4.1.9 Other incomes

Over half of the respondents (68.8%) had not non-farm income in past and in present these respondents decreased to 22.5%. In 2000, nearly all of the respondents (99.4%) did not receive remittances from abroad and these respondents decreased to 98.1% in 2018 (Table 4.116). Changes of non-farm income of respondents were significantly varied according to group of non-farm income they got (χ^2=11.3, $p < 0.01$). The respondents (70%) who have not non-farm income in past obtained non-farm income in present. The chi-square analysis showed that this change was significant during 20 years (Table 4.117).

4.1.10 Climate constraints

Drought problem encountered by 65.6% of respondents in past and this problem was decreased because 46.9% of respondents pointed out in present. Flooding problem was encountered by only 2.5% of respondents in both past and present. Twenty percent of respondents faced with rain damage during harvesting in past and increased to 20% in present. In 2000, 20% of respondents did not meet climate constraints and increased to 30.6% in 2018 (Table 4.118). Changes of climate constraints encountered by respondents were significantly varied according to group of climate constraints they met (χ^2=236.7, $p < 0.01$). The respondents who encountered drought problem in past faced rain damage problem (19%), after that 11.4% of them did not encounter climate constraints at present. Among the respondents who faced flooding problem in past 25% of them changed to drought problem in 2018. In 2000, 6.3% of respondents were met with rain damage problem and in 2018 they met with drought and then 3.1% of them had no climate constraints (Table 4.119).

Table 4.114 Most expensive activities in rice production of respondents between 2000 and 2018 in Meiktila Township

Most expensive activities	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Establishment	154	96.3	147	91.9
Fertilizer	-	-	3	1.9
Harvesting	6	3.8	10	6.3
Total	160	100.0	160	100.0

Table 4.115 Changes of most expensive activities in rice production of respondents between 2000 and 2018 in Meiktila Township

Most expensive activities (2000)	Respondents (n=160)		
	Most expensive activities (2018)		
	Establishment	Fertilizer	Harvesting
Establishment	146 (94.8)	3 (1.9)	5 (3.2)
Harvesting	1 (16.7)	0 (0.0)	5 (83.3)
χ^2		63.2**	

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.116 Other incomes of respondents between 2000 and 2018 in Meiktila Township

Other incomes	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Non-farm income				
No	110	68.8	36	22.5
Yes	50	31.3	124	77.5
Total	160	100.0	160	100.0
Remittances				
No	159	99.4	157	98.1
Yes	1	0.6	3	1.9
Total	160	100.0	160	100.0

Table 4.117 Changes of non-farm income of respondents between 2000 and 2018 in Meiktila Township

Non-farm income (2000)	Respondents (n=160)	
	Non-farm income (2018)	
	No	Yes
No	33 (30.0)	77 (70.0)
Yes	3 (6.0)	47 (94.0)
χ^2	11.3**	

Figures in the parentheses are percentages.

** = significance at 1% level

Table 4.118 Climate constraints encountered by respondents between 2000 and 2018 in Meiktila Township

Climate constraints	Respondents (n=160)			
	2000		2018	
	Frequency	Percentage	Frequency	Percentage
Drought	105	65.6	75	46.9
Flood	4	2.5	4	2.5
Rain damage	19	11.9	32	20.0
None	32	20.0	49	30.6
Total	160	100.0	160	100.0

Table 4.119 Changes of climate constraints encountered by respondents between 2000 and 2018 in Meiktila Township

Climate constraints (2000)	Respondents (n=160)			
	Climate constraints (2018)			
	Drought	Flooding	Rain damage	None
Drought	72 (68.6)	1 (1.0)	20 (19.0)	12 (11.4)
Flooding	1 (25.0)	3 (75.0)	0 (0.0)	0 (0.0)
Rain damage	2 (6.3)	0 (0.0)	29 (90.6)	1 (3.1)
None	0 (0.0)	0 (0.0)	0 (0.0)	19 (100.0)
χ^2	236.7**			

Figures in the parentheses are percentages.

** = significance at 1% level

4.2 Discussion

Wet season

(a) Farm holding

According to t test, total farm size and rice areas of respondents were significantly decreased between 2000 and 2018. Because of less rainfall, less developed irrigation channel and no meet the irrigation need of their field areas, the respondents reduced their rice growing areas. As a result of droughts and water shortage, area has decreased. There is limited potential for further increase of the rice area. Because all area has to be irrigated and rice is a high water-consuming crop, supply of irrigation water is the most important limiting factor (Food and Agriculture Organization [FAO], 2003). Although total farm size and rice areas of respondents were decreased between 2000 and 2018, they could cultivate rice not only wet season but also dry season due to develop some irrigation channel.

(b) Varietal changes

The majority of respondents were used traditional to improved rice varieties during 2000 and 2018. Improved varieties gave high yield, market demand and better price that why they used this variety. And also this variety was medium duration and they could grow in right time when water is available. The introduction of genotypes/varieties with tolerance to drought, salinity and cold temperature can increase further productivity. In Egypt for instance, potential water saving induced by the use of short-season rice is in comparison with long-season rice (FAO, 2003).

Between 2000 and 2018, uses of certified seed by respondents were increased due to easy to access and training by extension agents. The Department of Agriculture (DoA) is responsible for coordination of farm advisory services and research across the country, for agricultural education and for the delivery of farm inputs including seeds and farm advisory services. Furthermore, the Ministry of Agriculture and Irrigation (MOAI) has been working with the donor community to develop a range of new improved varieties for a range of crops grown in the Central Dry Zone (CDZ), and these cultivars are now being multiplied by government using their seed farms and seed multiplication personnel. However, current levels of seed production for the crops important to the CDZ are completely inadequate to meet even the smallest demand for improved seed (FAO, 2014).

(c) Changes of tillage operation and crop establishment

Land preparation methods of respondents were changed between 2000 and 2018. They used machine instead of animal for land preparation because of less-time consuming and good tillage. It reduces drudgery and save time in of routine farm operations (Mada & Mahai, 2013). According to changes of mechanization, most of the respondents (81.9%) practiced two strokes of tillage operation in 2018. During 2000 and 2018, rice establishment methods of respondents were not significantly different for wet season. Almost all of the respondents usually practiced transplanting method because of water shortage and weed problem. The transplanted rice culture increased weed suppression, easy seedling establishment, and creating anaerobic conditions to enhance nutrient availability. Average hired labours uses were significantly increased between 2000 and 2018. In past, they cultivate rice in one season and in present they changed to cultivate rice in two seasons and also they changed to use medium duration varieties. Due to this, they need to finish in time for next season rice growing and hence they hired more labours for rice establishment.

(d) Crop management practices

Water irrigation sources and management practiced by respondents were changed between past and present but no significant. However, most of the respondents were changed to practice intermittent irrigation from permanent flooding due to improve some irrigation channel by government support. Uses of chemical fertilizer (N,P,K) of respondents were increased in 2018. As a consequence of the introduction of chemical fertilizer companies and training by extension staff but farmers used higher than the recommended rate (57.5 N kg per ha, 12.7 P kg per ha, 15.6 K kg per ha) especially in N fertilizer because they thought that the more applied fertilizer the more get high yield. During 20 years, frequency of fertilizer application was not significant different but frequency of fertilizer application were increased. They changed to practice two-split and three-split fertilizer application. These practices have more affective for rice growing stages and reduce wastage of fertilizer. According to the result, family labours used by respondents were significantly increased and inversely, hired labours were significantly decreased for fertilizer application. Because of most of the respondents are smallholders and fertilizer application can finish by using family labours even they did not hire labours.

Weed management practiced by respondents were not significantly different during 20 year. No serious weed problems were engaged by most respondents and hence they have no weeding for wet season. In 2000, only 1.9% of respondents used chemical (pesticide) to control pests and diseases and these respondents significantly increased to 66.3% in 2018. Pests and diseases control was steadily adopted by both pesticide users and non-users found in 2000.

Harvesting methods of wet season rice practiced by respondents were not significantly different between 2000 and 2018. However, some respondents who didn't used combine harvester changed to use because of combine harvester was less time consuming and harvesting to winnowing processes were done at once. Family and hired labours for harvesting and threshing were used by respondents were significantly decreased between 2000 and 2018 as a result of usage of mechanical instead of manual. Agricultural mechanization also could importantly contribute to increases in profitability from increased crop production and reduced costs of cultivation, transport and processing by reducing expenditure on labours (Sims & Kienzle, 2006). Rice yield of respondents was significantly increased between 2000 and 2018. Most of the respondents were used improved varieties; more fertilizer application and appropriate split fertilizer application due to this their total yield increased in 2018.

Dry season

(a) Cultural practices (2018)

Most of the respondents (95.5%) used machine for land preparation. They used improved varieties (Manawthukha) (76.6%) and practiced transplanting method (98.2%). For water management, they practiced intermittent irrigation (89.2%) due to easy to control drainage by improving irrigation channel. They used manual weeding (53.2%) and some respondents still did not control weed because no serious weed problem was engaged in their area. Pest and disease problems were controlled by chemical (64.9%). And then they used combined harvester (95.5%) for harvesting and threshing operation. Average rice yield for dry season was 4.5 tons per ha at 2018 (Table 10).

Postharvest activities for both seasons

For the production of better quality rice and seed, the respondents (92.5%) who operated rice grain drying process before selling to market slightly increased to 93.8% in 2018. Total amount of rice selling significantly increased because total rice yield

increased and demand available for this variety. Most of the respondents kept rice for home consumption and seed (next season) in both 2000 and 2018.

Other incomes

Non-farm incomes of respondents were increased in 2000 and 2018 but no significant. According to reduced area and lower income from agriculture, they were trying to find another job as human hair enterprises (to untangle and straighten hair). In study area, sales of human hair up because of Chinese demand.

CHAPTER V
CONCLUSION

The study attempted to investigate changes of rice production system between 2000 and 2018 in the study area. Evidence was found that water insufficient in the study area caused reduction in rice productivity in the last 20 years. But the respondents changed to cultivate rice two times per year (rice-rice) due to irrigation channel available in some areas starting from 2015.

The respondents changed to use machine in land preparation to catch moisture and led to reduces labours usage and thereby making the work faster and easier. Then uses of traditional long duration varieties (Ngasein) were changed to improved medium duration varieties (Manawthukha). After 20 years, they got high yield of rice in present by using improved varieties and increase amounts of chemical fertilizer application due to introduce by extension workers. Besides that they changed to practice intermittent irrigation because of improve irrigation channel by governmental support. Nowadays, cultural practices of respondents were changed to new improve practices, in weed, pest and disease managements and fertilizer supplies however nearly half of the respondents did not change in the study area.

Based on the result findings, it can be said that water was one of the most limiting factors for development in general and agriculture in particular. And the other limiting factor was fertilizer application; they were considering how to make further increase their harvest, though they did not know the advantages and disadvantages of the different fertilizers. Farmers' fertilizer use was often at inefficient application rates and inappropriate nutrient composition.

In the study area, some changes were found between 2000 and 2018, however, prominent changes in rice production system were not observed. Therefore, based on this study, policy makers and all stakeholders involved in rice value chain should be taken into consideration of some recommendations for improving rice production systems in central dry zone.

Recommendation

1. The climatic regime cannot be modified, but it can certainly improve the crop management of and technical support to rice farmers to improve rice productivity.

2. The introduction of genotypes/varieties with tolerance to drought can increase further productivity.
3. The seed production sector should be strengthened to supply quality seeds with affordable price to farmers. Furthermore, farmers should be trained to carefully manage their own seed production fields.
4. A diversified agriculture should be practiced for sustainable in the long run. Present rice culture systems require more water than most other food crops.
5. The new knowledge and technologies are not still reaching all of the farmers. There are considerable knowledge gaps between researchers, extension agents, and farmers. The combinations of public, private, cooperative and Non-Governmental Organization (NGO) extension agencies should be needed to spread new knowledge and technologies to farmers.
6. Irrigation infrastructure should be expended and systematically managed by government and local farmers

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