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The FFTC Journal of Agricultural Policy

FFTC Agricultural Policy Platform

Research Initiatives towards Implementation of Climate Smart Agriculture (CSA) Practices for Rice and Other Crops in Malaysia

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Received January 10, 2023; Accepted October 24, 2023

ABSTRACT

Climate change continues to be a major focus area for researchers and policy makers. Its impacts could threaten national food security by potentially reducing crop yield in both commodity and non-commodity subsectors. Within the non-commodity agrofood industry in Malaysia, which includes rice production, the impacts of climate variability through events like droughts and floods will have long-term implications for its productivity. Additionally, these effects can be observed in other agrofood subsectors including fruits, vegetables, and livestock. Therefore, several adaptation and mitigation strategies using Climate Smart Agriculture (CSA) practices have been developed to effectively manage the potential climate risks while simultaneously aiming to optimize crop production. These strategies mainly focus on overcoming the impacts of the potentially higher local temperatures and prolonged dry spells associated with more extreme conditions. Research specializing in the rice subsector was previously and is still undertaken and it prioritizes approaches such as improving water management practices, identifying local accessions tolerant to drought, and the development of new varieties through marker-assisted breeding. Meanwhile, new strategies aimed at overcoming climatic issues in the fruits, vegetables, and livestock subsectors have included studies on potential alternative pollinators, overcoming pest and disease migration in highland vegetable production, developing new approaches to address fruit-setting failures related to elevated temperatures, and mitigating greenhouse gas (GHG) emissions. The next five years are crucial because more outputs from these studies might successfully address important domestic issues. The recently launched National Agriculture Policy 2.0 will spearhead the implementation of climate-resilient strategies, with the aim of creating a paradigm shift in the agricultural sector to ensure better adaptation to climate change and better performance to achieve sustainable agricultural production.

Keywords: Climate change, adaptation, mitigation, food security

INTRODUCTION

The agricultural industry plays a critical role in ensuring food security. The industry is placed at the highest food chain production tier and represents the most important part of the food production cycle.

In Malaysia, there is a lot of public interest concerning how climate change could affect the agricultural production (Mahmood & Guinto, 2022). Highly motivated by this call of the public, the policy makers and scientific communities have responded and addressed this issue using more holistic and comprehensive approaches (Selangorjournal, 2021). Malaysia is currently one of the countries that is making good progress in terms of promoting research activities that lead to enhanced agricultural resilience to climate change. The government has included the environmental pillar through the deployment of climate-resilient measures as one of the policy frameworks' cornerstones in the newly released National Agriculture Policy 2.0. (MAFI, 2022). The policy aims for a paradigm shift towards a sustainable food system capable of adapting to climate change.

Several research programmes have been developed to address the issues of climate change. The Malaysian Agricultural Research and Development Institute (MARDI) is one of the agricultural research institutes in Malaysia that has organized relevant research activities (Tapsir *et al.*, 2019). Together with the research and development (R&D) plans by other agencies and universities, positive progress has been observed in recent decades. Previously, the ongoing scenario at the international level was translated to the national level, where the focus had been more on the development of emissions accounting methods, mitigation approaches, and national inventory estimates (NRE, 2011). Improved emissions measurement has been developed for the agriculture sector, especially the emissions factor involved in methane emissions from rice and enteric fermentation from the livestock sector. The recent progress at the United Nations Framework Convention of Climate Change (UNFCCC) through the discussions on Koronivia Joint Work on Agriculture (KJWA) encouraged many countries, including Malaysia, to prioritize both adaptation and mitigation to a greater extent as both may eventually exist as co-benefits (UNFCCC, 2022).

Moreover, KJWA's key challenge is to help agriculture's climate initiatives to succeed with the support from the researchers, farmers, and policymakers (Ramifehiarivo *et al.*, 2022). These initiatives can be done through the adoption of the CSA practices that integrate the mitigation, adaptation, and food security (Husen *et al.*, 2022). In Malaysia's 11th Malaysia Plan (2016–2020), the CSA practices conducted by MARDI were specifically for the rice subsector, and the research has focused on farmers in granary and non-granary (water-scarce) areas (Hariz *et al*., 2020). In the subsequent five years of the 12th Malaysia Plan (2021–2025), using the same concept of the CSA practices, other important domestic issues related to climate change were highlighted (Abdullah *et al.*, 2021). These included pest and disease (P&D) issues with vegetable production in highland areas, as well as fruit production, which may sometimes be affected by occasional extreme events including haze (UNFCCC, 2021).

The proposed CSA practices in the 11th and 12th Malaysia Plan will eventually mature, and the CSA practices should be efficiently implemented. These practices could be accomplished by a realistic financial or investment plan by numerous parties and interests. The support that may come from the public or private sector (internationally or locally) will signify forms of acknowledgement and the procedures that have been followed to develop new technologies and transfer of the existing technologies to the farmers. These highlights and other recent updates are discussed in this paper. The flow begins with the research progress made in the last ten years and the ongoing research being conducted. The authors then discuss the implementation structures and proposed programmes for larger-scale CSA implementation.

RESEARCH PROGRESS INVOLVING THE CLIMATE SMART AGRICULTURE (CSA) FRAMEWORK IN THE RICE SUBSECTOR

Extreme occurrences of high temperature and low precipitation could increase the likelihood of drought and precipitation fluctuations, which would have a negative impact on rice production, the primary staple food in Malaysia (Firdaus *et al.*, 2020, Ahmad *et al.*, 2017). The granary areas in Malaysia rely mainly on irrigation schemes to supply water for cultivation (Hanafiah *et al.*, 2019). Thus, any changes to the pattern of precipitation or rainfall may have detrimental effects on rice production (Lee *et al.*, 2019). As a part of the 11th Malaysia Plan from 2016 until 2020, MARDI had embarked on R&D projects to address these issue (Hariz *et al.*, 2020). These projects included water management studies using the existing local rice variety named MARDI Siraj 297, the identification of local accessions tolerant to drought, and the development of a new rice variety with drought-tolerant traits. These strategies are highlighted in Figure 1.

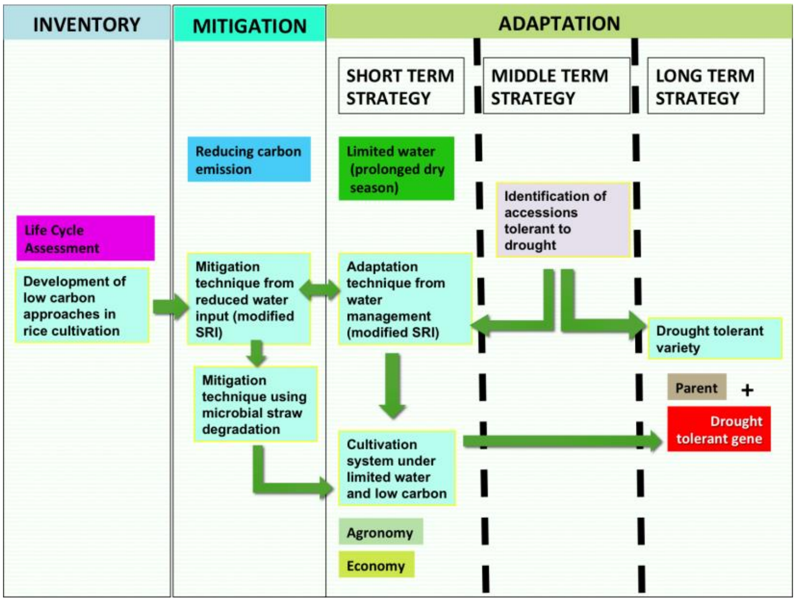

Figure 1. Research frameworks to address climate change issues of rice production in Malaysia. Water management studies were improved from the popular planting technique of System of Rice Intensification (SRI).

The objective of these research projects was to address the issues of adaptation, mitigation, and optimizing food security, which formed the backbone of the CSA practices. An earlier study in this subsector on GHG emissions was conducted to evaluate the total emissions from rice cultivation. The national inventory highlighted the anaerobic rice cultivation as one of the major emitters from agricultural activities in Malaysia (MESTECC, 2018). Following this, research utilizing the life cycle assessment (LCA) technique for rice cultivation determined that 76.85% (1.067 tons) of CO_2 eq/ton of emissions was contributed from the anaerobic methane emissions (Rahman *et al*., 2019). Therefore, proactive measures are required to reduce or limit the emissions from the flooded or anaerobic rice, which is a usual practice in rice cultivation.

Use of microorganisms to improve rice straw degradation

Rice straw is one of the biodegradable by-products of rice cultivation (Ain *et al.*, 2017). Rice is planted twice a year in Malaysia, and the planting seasons are categorized as the main season and the off-season (Tan *et al.*, 2021). During the dry season, straw is burned as part of postharvest management process (Rahman *et al.*, 2019). However, the management of straw, especially during the wet season, has been found to be challenging. It is not burnt and is instead integrated into the soil (Rosmiza *et al.*, 2014). During wet conditions, the soil is soft, and the straw is generally moist (Fazlyzan *et al*., 2022). This is the main reason burning is only carried out during the dry season. Thus, research was conducted to evaluate the potential of microorganisms to enhance the degradation of the rice straw in the fields. The research identified *Trichoderma* sp. as a candidate for enhancing straw decomposition. The results showed its constancy in enhancing C/N reduction and cumulatively increasing degrader enzyme production (Sadi *et al*., 2020, Fazlyzan *et al*., 2022). This process led to a reduction of 10.14% in GHG in the form of decreased anaerobic methane during the planting season in the field (Hariz *et al*., 2022).

Water management using a modified System of Rice Intensification (SRI) technique

Rice cultivation in saturated water condition leads to a development of cultivation using a water-saving technique (Afifah *et al*., 2015). A new technique developed by MARDI was slightly modified from the existing System of Rice Intensification (SRI), which has been used in rice cultivation. The objective of the study was to prepare farmers in water-deficit areas for the possibility of rice cultivation during periods of low water availability. In addition, it would make it possible to farm rice with much less water and a huge reduction in methane (CH_4) emissions. Using this technique, the maximum water level was set at saturated conditions, and the water table was allowed to reach 15 cm below the soil surface, or a soil water potential equivalent of −10/−15 kPa, before re-irrigation (Figure 2). This reduced the period of anaerobic conditions and thus the CH_4 emissions. The study highlighted a 30–

55% reduction in methane emissions from the 218.89 kg/ha/season average using conventional practices during flooded conditions. Meanwhile, the study also indicated no changes in the pest and disease management as the farmer's normal practices were followed (Aziz *et al.*, 2020). No significant weed incidence was also reported during the field trials as the saturated practice ensured the soil to maintain in a wet condition, and no drying period occurred. Therefore, it offers options related to both climate change adaptation and mitigation strategies while achieving the agronomic benefits. This study also indicated that a current Malaysian rice variety, MARDI Siraj 297, is suitable for cultivation under saturated water conditions.

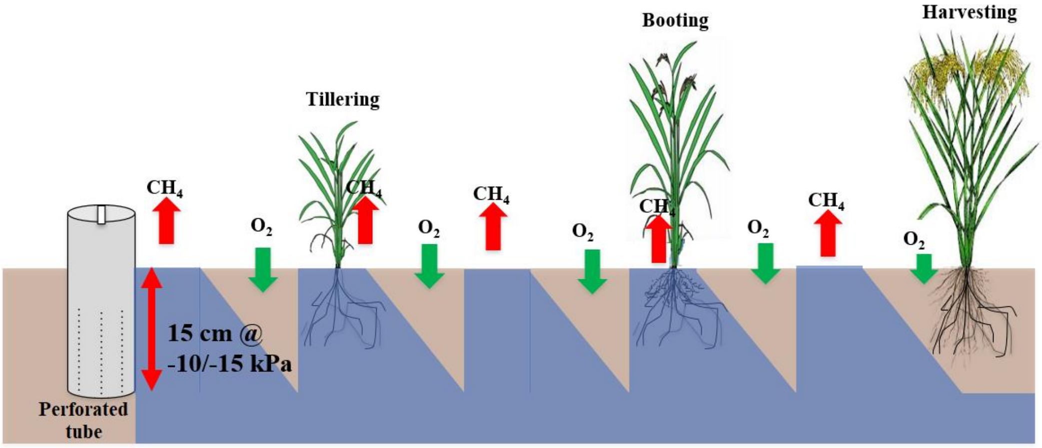

Figure 2. Method of planting under saturated water conditions studied by MARDI

Identification of rice accessions with drought-tolerant characteristics

The purpose of screening and identifying the existing accessions was to prepare farmers for any impending drought event, especially in non-granary areas. This would provide options for selecting suitable varieties to plant in the case of any potential drought events. This research was conducted by evaluating the physiological traits, morphological characteristics, and genotypic assessment of selected local varieties. The research identified five MARDI varieties namely MR269, MRQ76, MR253, MRQ74, and MARDI 284, whose potential yields increased under drought conditions and were comparable to that of the drought tolerant control variety, Dular (Site *et al*., 2021; Hariz *et al*., 2020). Table 1 highlights the ten varieties that possessed drought grain yield QTLs (DTY), namely MR219, MR220, MRQ74, MR253, MRQ76, MARDI Siraj 297, MARDI WANGI 88, MR269, MARDI 284, and MARDI SEBERNAS 307 (Site *et al.*, 2021). Further assessments using a genotypic study identified MR253, MRQ74, and MRQ76 as carriers of more than one drought grain QTL, with MRQ76 found to be the most prominent variety because it contained three QTLs. The morphoagronomic characteristics also showed the potential of these varieties, which were recommended to be planted during drought or dry period.

Table 1. List of QTLs appearing on selected MARDI-released varieties (Site *et al.*, 2021)

$qDTY_{3.2}$	$qDTY_{11.1}$	$qDTY_{2.3}$
MR219	MRQ74	MR253
MR220	MRQ76	MARDI WANGI 88
MRQ74		MARDI Siraj 297
MR253		SEBERNAS 307
MRQ76		MRQ76
MR269		
MARDI 284		

Progress development of new drought-tolerant variety

A breeding programme was carried out by the introgression of several qDTYs into the high-yielding variety of MARDI Siraj 297. This research activity began in 2016, and the development of new advanced lines is currently in progress. There are several potential lines, carrying either single or multiple qDTYs of qDTY2.3, qDTY6.1, qDTY 3.2, and qDTY 11.1, with 44 lines selected for BC3F2 lines as of 2020 (Shamsul Amri *et al*., 2020). A recent result in 2022 showed that the BC3F3 lines had superior plant growth and yield production under both mild and severe drought stress, compared to the recurrent parent (Rahiniza *et al*., 2022). The use of the Marker Assisted Selection (MAS) tool was found to have effectively eliminated any unwanted breeding lines. Eventually, the research aimed to develop a uniform and stable rice variety that can be utilised by rice growers.

RESEARCH PROGRESS ON RICE AND OTHER CROPS (FRUITS AND VEGETABLES) INCLUDING LIVESTOCK SUBSECTORS UNDER THE 12TH MALAYSIA PLAN

Under the 12th Malaysia Plan, which runs from 2021 until 2025, there are continuous research programmes to promote new technologies developed from the R&D in the rice subsector. A new variety development has been intensified in terms of stabilizing the advance lines. The research is being funded through the continuous funds under the 12th Malaysia Plan by the government. It is hoped that a mature and stable variety can be reached by the end of the 5-year research programme. Meanwhile, the water-saving and straw management techniques are currently undergoing documentation processes as a rice cultivation package, which will later be promoted among the farmers. Similarly, the fragrant rice variety MRQ 76, which has been widely planted in non-granary areas, has been given a boost from the recent research findings. With the new data on its drought tolerant viability, it will further justify and enhance its market values among the farmers and the public.

Extensive research is also currently being implemented to address various issues related to climate change (Figure 3), in addition to the study on the rice subsector. These include the potential increases in temperature, particularly heat waves, which might affect the fruit setting of selected fruit crops. Therefore, a study to find a solution is being undertaken. Moreover, pest and disease issues are also affecting the highland vegetable production (Rasdi & Rahman, 2022). Therefore, simulation research is carried out with the aim of developing new pest and disease management procedures for specific vegetable production areas. Damages to ecosystem services are also being given attention to, with a thorough study highlighting the potential use of stingless bees as alternative pollinators are in progress after a recent study showed that it can pollinate other important fruit crops including durian (Fahimee *et al*., 2021). There are also specific projects for mitigating GHG emissions in agriculture, focusing on GHG reductions from the peat and livestock subsectors. Nitrous oxide emission from peat soil and methane emission from livestock have also been a matter of concern for these subsectors (Jeffary *et al.*, 2021, Azizi *et al.*, 2017).

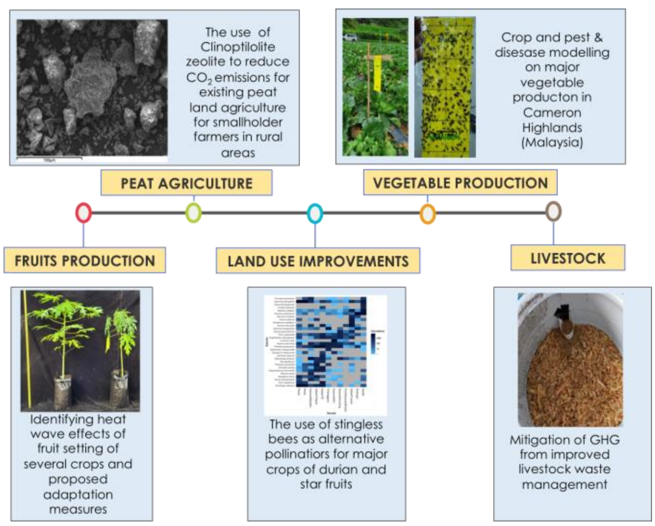

Figure 3. Research conducted in the fruits, vegetables, and livestock subsectors (2021–2025)

STRATEGIES TO IMPLEMENT CLIMATE SMART AGRICULTURE (CSA) TECHNOLOGIES TO THE STAKEHOLDERS

It is imperative to highlight that climate change will be an important factor in future agricultural activities. To optimize the outputs, local problem-solving technologies must be developed simultaneously. Several technological developments have been made by either the public or private sectors including those mentioned earlier. At this stage, the priorities are to provide financial platforms for CSA activities to be effectively delivered to vulnerable people such as rural farmers, non-granary paddy planters, and various farmers' organizations. Knowledge and information about the new technologies developed at MARDI are spread through knowledge-sharing and national consultation to improve institutional arrangements, especially government policies. In addition, new projects to improve CSA guidelines and financial structures to enable local CSA implementation have also been undertaken. Some of the implemented programmes are highlighted in Table 2.

Table 2. Program and activities to implement Climate Smart Agriculture (CSA)

Programs and activities	References
National consultation on cross-sectoral adaptation strategies (including agriculture) through national reports and knowledge/technological extensions	MESTECC (2018), BERNAMA (2021)
Collaboration between agencies by forming technical working groups to expedite technology transfer	BERNAMA (2022)
Developing regional guidelines to implement CSA activities	ASEAN-CRN (2021)
Developing and participating in regional projects to enhance climate finance for those agricultural activities specifically affected by climate change	GCF (2022)

CONCLUSION

The current research studies have progressed very well in terms of developing Climate Smart Agriculture (CSA) practices in Malaysia. There have been several successes, with recent studies showing Malaysia's most popular rice variety, MARDI Siraj 297 might be able to tolerate cultivation under limited or saturated water conditions. MARDI Siraj 297 has shown a promising yield and adaptability under dry spell especially in granary areas. In addition, research has revealed a local specialty rice variety, MRQ76 that possesses drought-tolerant characteristics and could be introduced to farmers in non-granary areas, which are most affected by limited water availability. In addition, research also continues to address the issues in other crops subsectors such as the fruits, vegetables, and livestock. With the assistance of government policies and the ongoing efforts to effectively transfer CSA technologies to farmers, the initiatives undertaken are expected to contribute to the implementation of climate change strategies.

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ACKNOWLEDGEMENTS

The authors would like to thank Dr Mohd Shukri Bin Mat Ali @ Ibrahim for his continuous support during the implementation of the project.

AUTHORS' CONTRIBUTIONS

Mohammad Hariz Bin Abdul Rahman: Conceived, designed, and performed the research; Wrote the manuscripts. Mohd Fairuz Bin Md. Suptian: Conceived and designed the research. Mohd Aziz Bin Rashid: Designed and performed the research related to the rice and fruits subsector. Saiful Zaimi Bin Jamil, Nurul Atilia Shafienaz Binti Hanifah and Rozimah Binti Muhamad Rasdi: Designed and performed the research related to the fruits and vegetable subsector. Fauzi Bin Jumat, Shamsul Amri Bin Saidon, Rahiniza Binti Kamaruzaman, Site Noorzuraini Binti Abd Rahman, and Mohd Shahril Firdaus Bin Ab Razak: Design and performed the research related to the rice subsector.

CONFLICT OF INTEREST

The authors declare no conflict of interest.